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AN AURAL DETECTION MODEL

Donald C. Taylor, et al

Army Missile Command
Redstone Arsenal, Alabama

May 1973

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TECHNICAL REPORT

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by

Donald C. Taylor
Arthur C. Poe

May 1972

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U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama

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13. ABSTRACT

This report describes an aural detection model for detection of low flying aircraft. It incorporates ambient sound pressure levels, weather conditions (including wind effects), and attenuations of the signal along the flight path, and allows target signatures to be inputed as measured at aspect angles. The output of the model includes a probability of detection versus time together with all pertinent conditions at time of detection.

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CONTENTS

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1. Introduction

This report describes a mathematical model to calculate aural detection of low flying aircraft. Instead of trying to modify an existing model computer program [1], it was decided to construct a new program based on an 8-step method [2,3]. Guidelines were to develop a model with one observer and one aircraft.

The main purpose of the new model program (Figure 1) is to compute the probability of aural detection with time. Aural detection is based on an incremental change in loudness level above the ambient level. The loudness level is a method of analysis for complex sound by relative judgments to a 1000-hertz tone. The units of loudness and loudness level are sones and phons, respectively, and will be described further in Section 3.

One item of concern in the model is in the human detection portion. The data used to simulate human detection were based upon two subjects. If available, better data should be incorporated into the model to give a truer representation of a human observer.

2. Prediction Procedure

In predicting the noise level which will be received by the observer on the ground from an airborne source, it is necessary to know the following:

a) The sound pressure level (SPL) at a known reference distance from the source

b) The distance from the source to the point of observation on the ground.

c) The sound-propagation characteristics of the atmosphere along the path between the source and the ground point [2].

When measuring the sound signature of the aircraft at a known distance, the distance should be close to the aircraft to limit atmospheric effects on the propagation of the sound. Aircraft sounds are directional and must be treated as such when taking measurements at a known reference distance [2]. The SPL at the observer is calculated by:

$$SPL = SPL_o - 20 \log_{10}\left(\frac{d}{d_o}\right) - A$$

$$\text{dB re } 0.0002 \text{ dyne/cm}^2 \qquad (1)$$

where

SPL_o = reference sound pressure level (dB)

d_o = distance from source at which reference level is measured

d = distance from source to observer

A = total attenuation (dB) over distance $d - d_o$.

The term, $20 \log_{10}(d/d_o)$, in Equation (1) is the reduction in SPL due to spherical divergence of the sound wave in spreading outward from the source, commonly referred to as "inverse square law attenuation." It is equivalent to a 6-decibel reduction in SPL for each successive doubling of distance from the source [2].

Total attenuation, A, is determined by three types of attenuation constants: (a) atmospheric absorption due to humidity, (b) atmoshperic abosrption in excess of humidity, in particular scattering of sound waves due to inhomogeneity and turbulence in the atmosphere, and (c) attenuation due to terrain absorption.

$$A = A_H + A_o + A_T \tag{2}$$

where

A_H = atmospheric absorption due to humidity

A_o = residual attenuation (atmospheric absorption in excess of humidity attenuation)

A_T = terrain absorption.

Humidity attenuation, A_H, can be calculated by the formula expressed as an attenuation coefficient, a_H, in decibels/1000 feet [2]:

$$A_H = a_H \left(d - d_o\right) \tag{3}$$

where

$$a_H = 0.1\ f\ (T + 45)/[(f/h^2) + (h^2/f)]$$

d, d_o = slant distance (1000 feet)

f = geometric mean frequency of an octave band (kilocycles).

T = temperature (°F).

Charts of a_H plotted against absolute humidity and temperature for various octave frequency bands are given in Figure 2 [2].

A_o, residual attenuation, is due principally to the scattering effects of air turbulence. Calculation of A_o depends on whether the observer is in a sound shadow. The shadow region is due to upward refracted sound rays and corresponds to a region in which sound is highly attenuated. This refraction is due to a decrease in sound velocity with increasing altitude. To calculate whether shadow formation has occurred, the following procedure is followed. The sound velocity in a given horizontal direction in the atmosphere depends on the temperature and on the vector addition of the component of wind velocity in that direction. The sound velocity, c, is given by the expression:

$$c = c_T + c_W \tag{4}$$

where

c_T = the sound velocity determined by temperature at the given point

$$c_W = W_{30} \cos (\phi) \tag{5}$$

W_{30} = the wind speed at 30 feet height

ϕ = the wind sound angle (Appendix A)

$$W_{30} = \frac{W_z}{1 + 0.27 \log_{10} \left(\frac{z}{30}\right)} \text{ mph} \tag{6}$$

W_z = the known wind magnitude at height, z.

Sound propagation in directions for which c_W is positive is referred to as "downwind" propagation and "upwind" propagation for negative c_W. When the variation of c_T and c_W with height is such that the net sound velocity, c, decreases with height, sound rays will be refracted upward as shown in Figure 3. To determine if the observer is in a sound shadow, use Figure 4 to find R_o, the horizontal distance from source to shadow boundary. This calls for the calculation of the logarithmic gradient, B, defined by:

$$B = B_T + B_W \tag{7}$$

where

$$B_T = 4\ K \times 10^{-4} \tag{8}$$

$$K = \frac{T - T_o}{\log_{10}\left(\frac{z}{z_o}\right)} \tag{9}$$

where

T, T_o = temperature at target and observer

z, z_o = height of target and observer

$$B_W = 1.5\ W_{30} \cos(\theta) \times 10^{-4} \quad . \tag{10}$$

If the horizontal distance from source to receiver, r, is greater than 3 R_o, the observation point will be in a sound shadow. The calculation of A_o when the observer is in a sound shadow follows. For wind sound angles between 110 and 150 degrees, use a value of 30 decibels for residual attenuation, A_o. Otherwise, determine A_o at the distance, R_o, by Figure 5 (the curves have been extrapolated by the user for more versatile range requirements) and add an amount delta A_o, given by:

$$\Delta A_o = \left[(r - R_o)(30 - A_o)\right]\ 2\ R_o\ \text{dB} \quad . \tag{11}$$

Average values of residual attenuation, A_o, due to turbulence outside a sound shadow are plotted in Figure 5. Weather variables affect the estimation of residual attenuation for source elevation angles less than 2 degrees for all frequency bands and for elevation angles between 2 and 10 degrees for the 75- to 150-hertz band. Therefore, under these conditions average residual attenuation must be corrected by the formula:

$$A_o = \bar{A}_o - 0.3\, b_T\, (\Delta T + 4.5) + 0.12\, b_W\, (W_{30} - 9.5) \qquad (12)$$

where

A_o = predicted value of attenuation

$\bar{A}_o$ = average value given by curves of Figure 5.

ΔT = temperature gradient ($^\circ$F/1000 feet)

$\Delta T = 2\,(T_5 - T_{500})$

where

T_5 = known temperature at 5 feet height

T_{500} = temperature at 500 feet.

The coefficients, b_T and b_W, are given by Table 1. The temperature gradient, ΔT, is taken as positive when temperature at 5 feet is higher than that at 500 feet [2].

A_T allows the introduction of four types of terrain conditions for simulation: (1) open area, (2) 18-inch grass, (3) lightly treed, and (4) forest. Terrain absorption is dependent upon elevation angle, range, and frequency. The farther downrange and the smaller the elevation angle, the higher the absorption. Figure 6 and Table 2 show percent of terrain absorption coefficient versus elevation angle where 100-percent terrain absorption attenuation corresponds to 0-degree elevation angle. To utilize Figure 6 and Table 2, read a percentage factor from Figure 6 then multiply this factor by the appropriate terrain coefficient of Table 2. The corrected coefficient will be in terms of decibels/1000 feet [1].

3. Hearing and Detection

Noises differ in intensity at different frequencies. In aural detection one must consider: (a) ambient noise level, (b) signal embedded in the ambient level, and (c) the sensitivity of the ear to (a) and (b). One must compute the probability of detecting an incremental intensity level as the signal comes into the ambient level. To approach the problem in the above fashion, loudness levels have to be calculated: (a) loudness level of ambient alone and (b) loudness level when a signal has been added to the ambient level. Loudness levels pertain to the magnitude of the auditory sensation that a person experiences and should not be confused with other distinguishing characteristics of sound (pitch, penetrating or dull, etc.). Loudness and loudness levels are distinguished and measured in terms of sones and phons, respectively. Acousticians have chosen a 1000-hertz tone for the standard reference of the phon and sone. The phon level of an unknown sound is the SPL of a 1000-hertz tone that has been judged by listeners to equal the loudness of the unknown sound. The sone is the loudness adjudged to a 40-decibel, 1000-hertz tone [4]. One sone equals 40 phons (Fig. and is related by the equation:

$$\log_{10} N = 0.03\, L_n - 1.2 \qquad (13)$$

where N is the loudness (sones) and L_n is the loudness level (phons). With the method of calculating loudness in sones available, the stage is set to calculate probability of detection:

a) To calculate loudness of background alone (sones):

1) Calculate SPL in each octave band

2) Convert to sones in each octave band

3) Multiply all except the maximum sone value found by 0.3

4) Convert to phons by Equation (13) (this will put the loudness level in terms of decibels of a 1000-hertz tone).

b) To calculate loudness of signal plus ambient:

1) Calculate SPL of signal plus ambient in each octave band (this involves changing both signal and ambient to microbars, summing, and converting the sum back to decibels)

2) Convert to sones in each band using Figure 8.

3) Multiply all except the maximum sone value found by 0.3

4) Convert to phons by Equation (13).

These calculations will give decibel intensity values of sounds in terms of a 1000-hertz tone. Thus, the delta decibel value above the ambient loudness level can be calculated (Table 3). Using the Quantal Theory of Discrimination for detection of an incremental decibel when the increments are added to a continuous stimulus [5], it has been found that the listener finds it difficult to distinguish one-quantum changes in the stimulus from the changes which are constantly occurring. The difference reported 50 percent of the time is equivalent to 1.5 times the quantal increment (decibels). A difference reported 100 percent of the time corresponds to 2.0 times the quantum increment [5]. Table 4 shows the mean quantum increment for two persons in decibels as a function of sensation level. The sensation level used is the ambient loudness level. A normal distribution is used to find a probability of detecting a delta decibel increment. It is divided into 12 regions using the mean and standard deviations of Table 4. These data were plotted and smoothed out to give a more uniform curve. The standard deviations are based on the smoothed data. The regions correspond to the proportion of the listening population assumed to have that quantal increment.

A weighting factor (Table 5) describes a probability of an individual being in that region. Using the mean and standard deviations of Table 4, calculate the quantum increment of the midpoint of each of the 12 regions. To calculate the probability P, let

$$R' = \begin{cases} 1 & \text{if R is less than or equal to 1} \\ R & \text{if R is between 1 and 2} \\ 2 & \text{if R is greater than or equal to 2} \end{cases} \tag{14}$$

then

$$P = R' - 1 \tag{15}$$

Starting at the left of the distribution multiply each probability by the corresponding weighting factor given in Table 5, and sum up:

$$\text{Probability}_{\text{total}} = \sum_{i=1}^{12} \left(P_i \times \text{weighting factor, } i\right) \quad . \tag{16}$$

4. Summary

In predicting the SPL that will be received by the observer on the ground due to an airborne source, several factors must be considered. Step 1 is the target signature measured at a known reference distance at aspect angles around the aircraft. Conditions which must be known include: (a) temperature at observer along with a temperature gradient, (b) wind velocity vector at a known height, (c) the type of terrain (there are four types available for simulation in the model), (d) relative humidity, and (e) the target flight path. To estimate the SPL received by the observer, attenuation along the acoustic path must be accounted for. There are three types of attenuations in the model: (a) attenuation due to atmospheric absorption due to humidity, (b) attenuation due to terrain absorption, and (c) attenuation due to atmospheric absorption in excess of humidity, usually referred to as residual attenuation. In determining the value of residual attenuation one must consider if the observer is in a sound shadow. Shadow formation is due to upward refraction of sound rays, causing a highly attenuated region where detection is poor at best. The refraction is due to wind and temperature effects.

At this point the estimated SPL's of the ambient and signal received by the observer are known in the octave bands. The number of decibels of ambient plus signal is combined in each octave band by conversion of microbars, summing the two, and converting the sum back to decibels. The loudness in sones of ambient and ambient plus signal can be obtained at this stage by a simple mathematical procedure and the use of a table. The transformation from sones to phons is obtained by an equation. Since phons are equal to decibels of a 1000-hertz tone, the delta decibel can be calculated. Using t[illegible] delta decibel and a derived normal distribution, a probability of aural detection is obtained.

TABLE 1. COEFFICIENTS FOR PREDICTION OF ATTENUATION OF A_o DUE TO TURBULENCE

Source Elevation (deg)	Distance from Source (ft)	Frequency Band (Hz): 75 to 150		150 to 300		300 to 600		600 to 1200		1200 to 2400	
		b_T	b_W	b_T	b_W	b_T	b_W	b_T	b_W	b_T	b_W
2	1000	-2.5	4.8	-1.2	1.2	0.0	0.0	-0.5	2.6	-1.2	0.4
	2000	-1.5	4.4	-1.2	1.3	0.9	0.0	-0.6	3.9	-1.4	0.0
	3000			-1.2	0.0	1.7	0.0	-1.1	4.4		
	4000							-2.0	4.0		
5	1000	-0.7	2.4	*	*	*	*	*	*	*	*
	2000	-1.0	1.5	*	*	*	*	*	*	*	*
10	1000	1.2	-1.7	*	*	*	*	*	*	*	*
	2000	0.2	-1.6	*	*	*	*	*	*	*	*

*No significant correlation.

TABLE 2 TERRAIN ATTENUATION COEFFICIENT (dB/1000 FEET) AT ZERO ELEVATION ANGLE

Terrain \ Octave	75 / 150	150 / 300	300 / 600	600 / 1200	1200 / 2400
Open area	2.3	5.5	6.5	6.5	6.5
18-in. grass	4.0	9.6	10.8	10.8	10.8
Lightly treed	6.0	9.0	12.0	15.0	18.0
Forest	10.0	13.0	16.0	24.0	35.0

TABLE 3. EXAMPLE OF THE PREDICTION OF LOUDNESS LEVEL*

	Frequency Bands (Hz)				
	75 to 150	150 to 300	300 to 600	600 to 1200	1200 to 2400
<u>SPL</u>					
Signal	40.0	35.0	50.0	45.0	55.0
Ambient	35.0	40.0	45.0	45.0	50.0
Signal + Ambient	41.19	41.19	51.19	48.0	56.19
<u>Sones</u>					
Signal	0.16	0.38	2.2	1.5	3.4 max
Signal + Ambient	0.18	0.62	2.3	1.8	3.6 max

Predicted loudness in sones of signal: 0.3 (0.16 + 0.38 + 2.2 + 1.5) + 3.4 = 4.672

Predicted loudness in sones of signal + ambient: 0.3 (0.18 + 0.62 + 2.3 + 1.8) + 3.6 = 5.07

Conversion of signal from sones to phons: $(1.2 + \log_{10} 4.67)/0.03 = 62.31$ phons

Conversion of signal + ambient from sones to phons: $(1.2 + \log_{10} 5.07)/0.03 = 63.50$ phons

delta dB = (phons of signal + ambient) - (phons of signal alone)

63.50 62.51 = 1.19

*The sones values were estimated from the nomogram of Figure 8.

TABLE 4. QUANTAL INCREMENTS IN DECIBELS AS A FUNCTION OF SENSATION LEVEL

Sensation Level (dB)	Test Data Quantal Increment (dB)		Assumed Standard Deviation (dB)	Assumed Mean (dB)
	Subject 1	Subject 2		
3	2.37	2.37	--	--
5	2.21	1.51	0.115	1.625
10	0.81	0.81	0.040	0.80
12	0.67	0.61	0.03	0.65
15	0.58	0.45	0.025	0.495
20	0.33	0.37	0.025	0.365
25	0.31	0.37	0.025	0.315
32	0.27	0.27	0.025	0.295
35	0.27	0.34	0.025	0.295
45	0.29	0.30	0.025	0.295
52	0.27	0.31	0.025	0.295
55	0.27	0.34	0.025	0.295
70	0.27	0.32	0.025	0.295
82	0.22	0.32	0.035	0.285
85	0.22	0.33	0.040	0.280
100	0.19	0.27	0.040	0.230

TABLE 5. WEIGHTING FACTORS

Example:

Sensation level = 82 dB Mean = 0.285 Standard Deviation = 0.035 Calculated delta dB = 0.27	1. Set up distribution in one-half standard deviations (12 regions) 2. Assign weighting factors 3. Calculate midpoints of the intervals 4. Set up ratios 5. Check to see that the ratios do not exceed 2.0 or are below 1.0 6. Subtract 1.0 from each ratio to get P. 7. Multiply by weighting factors 8. Sum up

Region No.	Region Midpoint	Quantals Ratio (R)	P_i	Weighting Factor (W_i)	Weighting Factor × P_i
1	0.1875	1.44	0.44	0.005	0.0022
2	0.20625	1.31	0.31	0.017	0.00527
3	0.22375	1.21	0.21	0.044	0.00924
4	0.24125	1.12	0.12	0.092	0.01104
5	0.25875	1.05	0.05	0.150	0.00075
6	0.27625	0.977	0.00	0.192	0.0
7	0.29375	0.919	0.00	0.192	0.0
8	0.31125	0.867	0.00	0.150	0.0
9	0.32875	0.821	0.00	0.092	0.0
10	0.34625	0.779	0.00	0.044	0.0
11	0.36375	0.742	0.00	0.017	0.0
12	0.38125	0.708	0.00	0.005	0.0
				Σ (W_i × P_i)	= 0.02886*

*Probability of detection.

TABLE 5. CONTINUED

Example:	
Sensation level = 35 dB Mean = 0.295 Standard Deviation = 0.025 Calculated delta dB = 0.46	1. Set up distribution in one-half standard deviations (12 regions) 2. Assign weighting factors 3. Calculate midpoints of the intervals 4. Set up ratios 5. Check to see that the ratios do not exceed 2.0 or are below 1.0 6. Subtract 1.0 from each ratio to get P. 7. Multiply by weighting factors 8. Sum up

Region No.	Region Midpoint	Quantals Ratio (R)	P_i	Weighting Factor (W_i)	Weighting Factor × P_i
1	0.22625	2.033149	1.0	0.005	0.005
2	0.23875	1.92670	0.9267	0.017	0.01575
3	0.25125	1.8308	0.8308	0.044	0.0365
4	0.26375	1.744	0.7440	0.092	0.6844
5	0.27625	1.665	0.6650	0.150	0.09975
6	0.28875	1.593	0.5930	0.192	0.113856
7	0.30125	1.5269	0.5269	0.192	0.1011648
8	0.31375	1.46613	0.4661	0.150	0.069915
9	0.32625	1.4099	0.4099	0.092	0.0377108
10	0.33875	1.3579	0.3579	0.044	0.0157476
11	0.35125	1.309	0.3090	0.017	0.005253
12	0.36375	1.2646	0.2646	0.005	0.001325
				$\Sigma (W_i \times P_i)$ = 0.570410*	

*Probability of detection.

TABLE 5. CONCLUDED

Example:

Sensation level = 20 dB
Mean = 0.025
Standard deviations = 0.025
Calculated delta dB = 0.50

1. Set up distribution in one-half standard deviations (12 regions)
2. Assign weighting factors
3. Calculate midpoints of the intervals
4. Set up ratios
5. Check to see that the ratios do not exceed 2.0 or are below 1.0
6. Subtract 1.0 from each ratio to get P.
7. Multiply by weighting factors
8. Sum up

Region No.	Region Midpoint	Quantals Ratio (R)	P_i	Weighting Factor (W_i)	Weighting Factor × P_i
1	0.29625	1.6877	0.6877	0.005	0.0034385
2	0.30875	1.6194	0.6194	0.017	0.0105298
3	0.32125	1.5564	0.5564	0.044	0.0244816
4	0.33375	1.498	0.4980	0.092	0.459816
5	0.34625	1.444	0.4440	0.150	0.0666
6	0.35875	1.3937	0.3937	0.192	0.07559
7	0.37125	1.3468	0.3468	0.192	0.0881568
8	0.38375	1.3029	0.3029	0.150	0.045435
9	0.39625	1.2618	0.2618	0.092	0.0240856
10	0.40875	1.2232	0.2232	0.044	0.0098208
11	0.42125	1.1869	0.1869	0.017	0.0031773
12	0.43375	1.1527	0.1527	0.055	0.0007635
				$\Sigma (W_i \times P_i)$ =	0.3678949*

*Probability of detection.

NOTE: The weighting factor is the probability that an observer chosen at random will be in that interval. The ratio is the number of quantals. 1.0 quantal represents 0-percent detection, 1.5 quantals represent 50-percent detection, and 2.0 quantals represent 100-percent detection. The total probability of detection is then the summation over the 12 regions of weighting times probability.

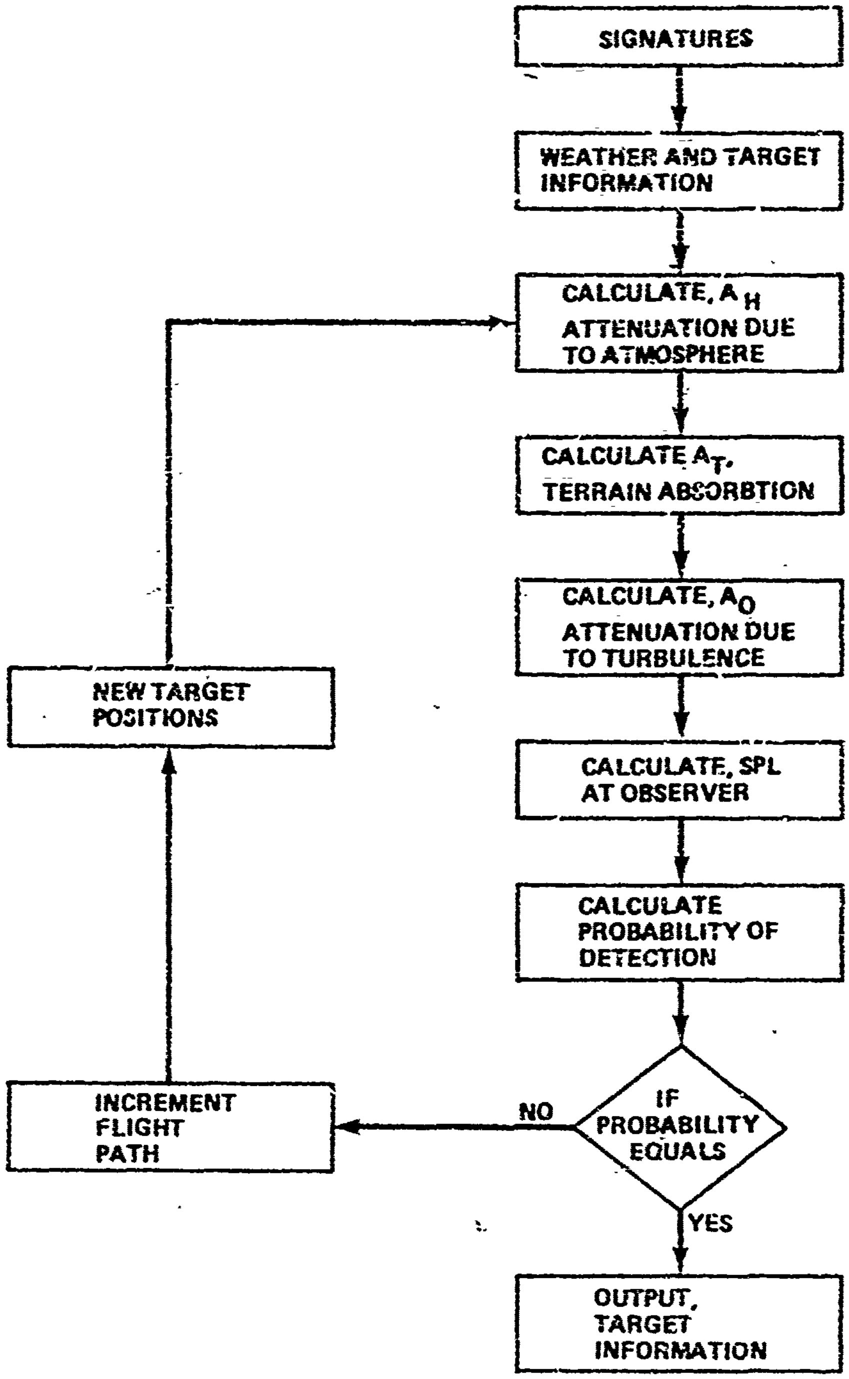


Figure 1. General flow diagram of the aural detection model.

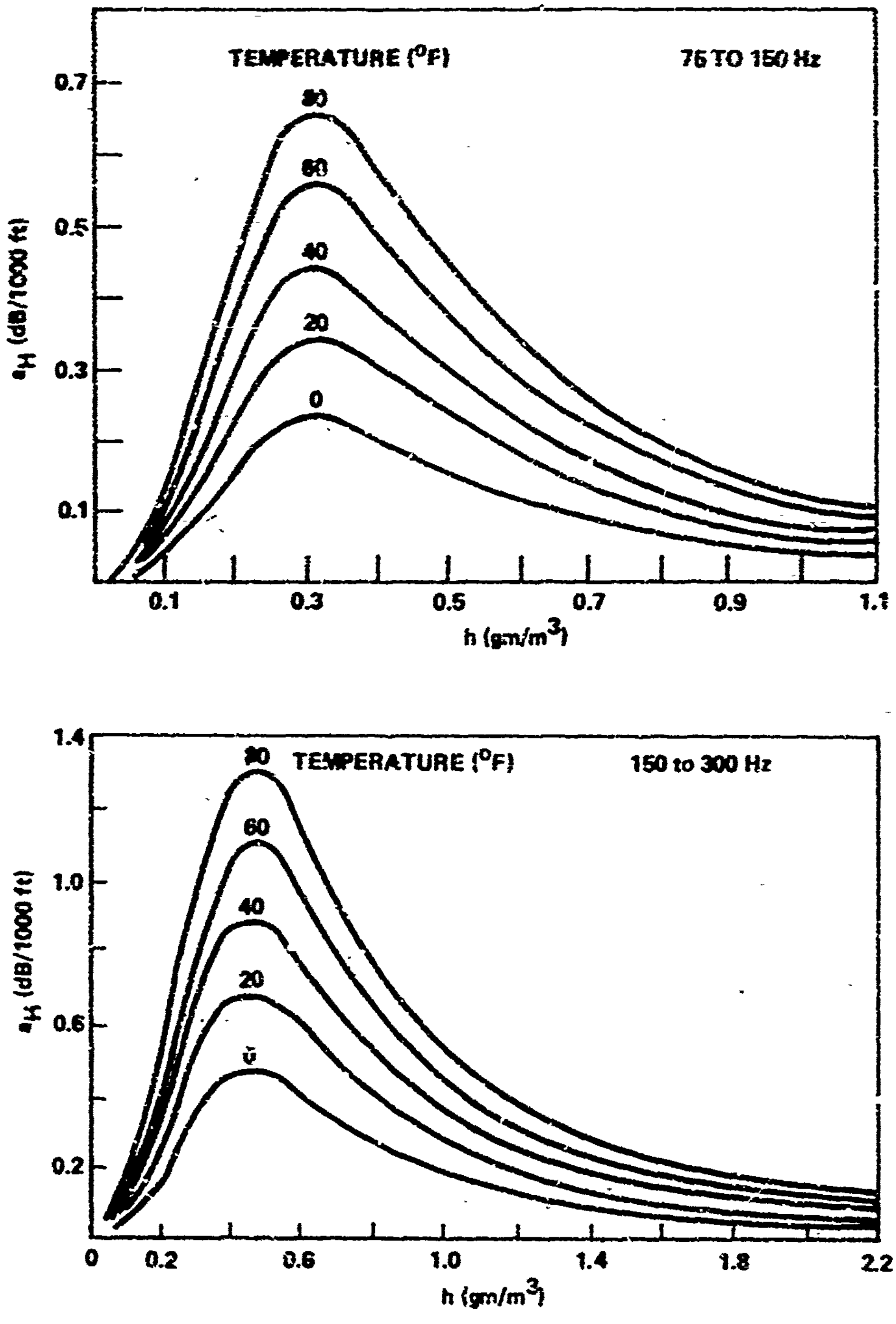


Figure 2. Relation of humidity attenuation coefficient to temperature and absolute humidity, h.

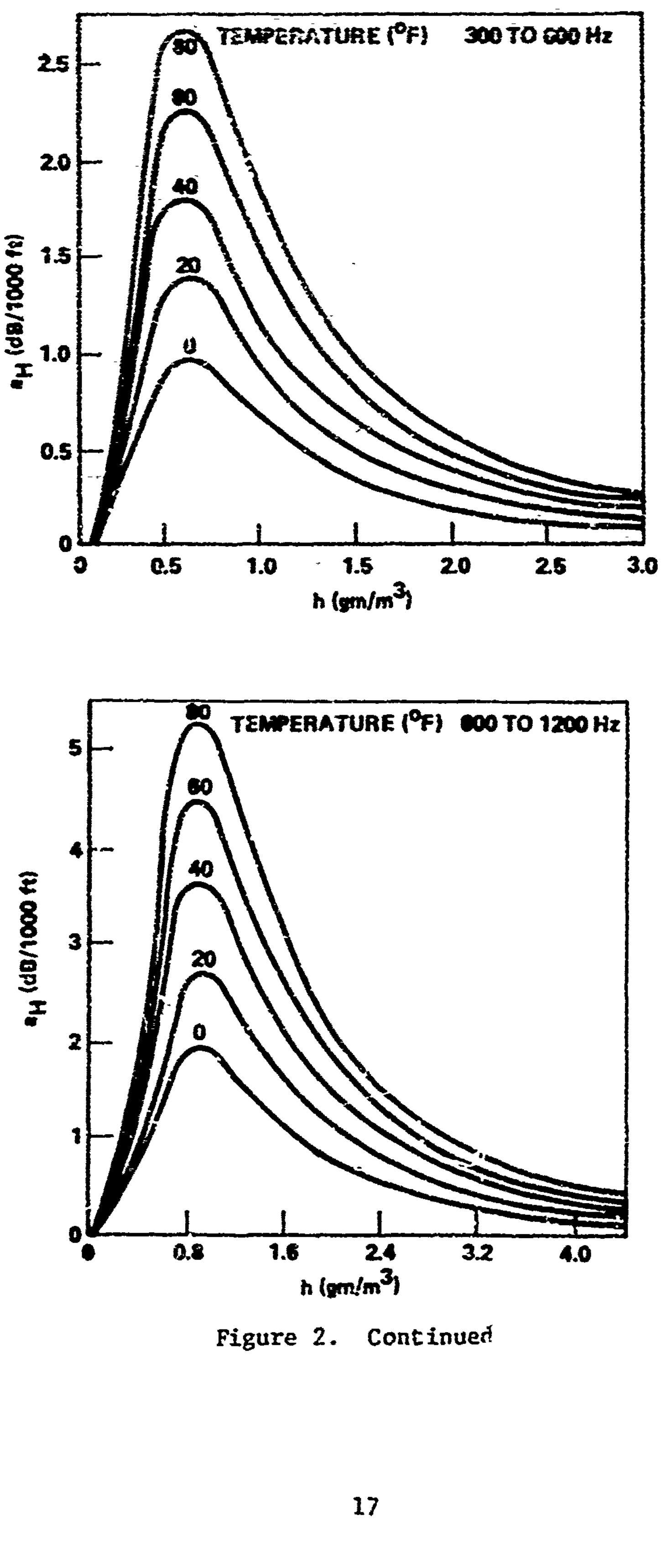


Figure 2. Continued

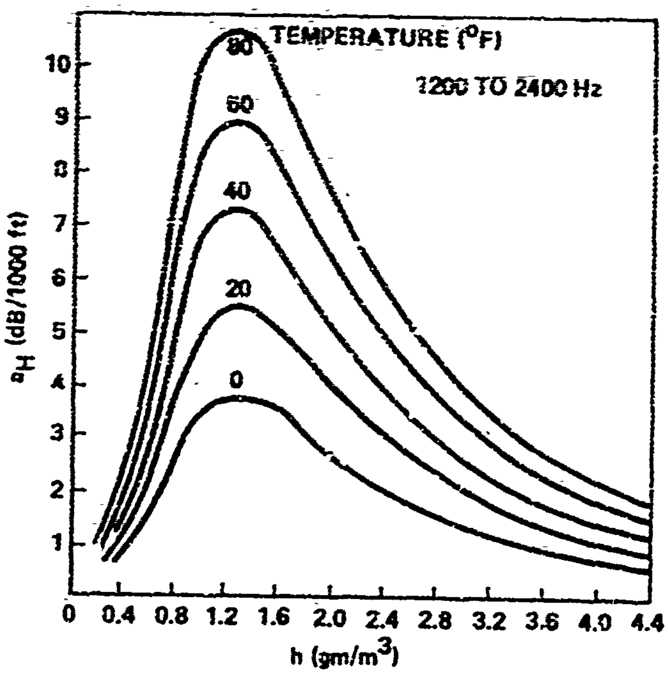


Figure 2. Concluded

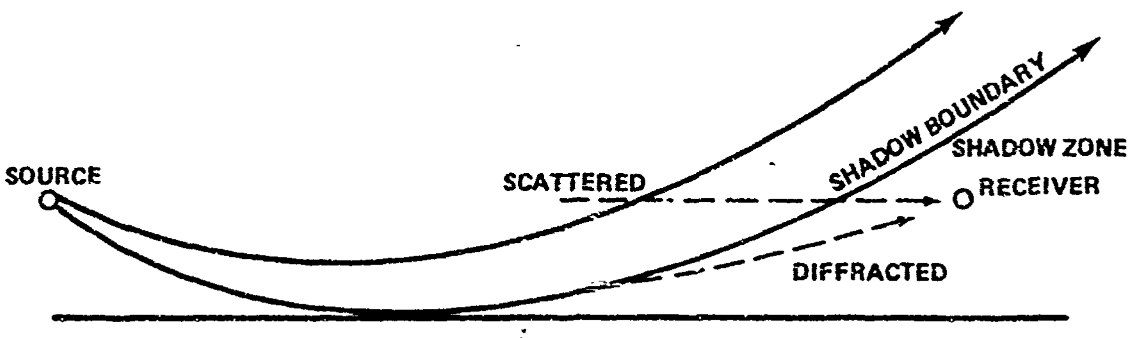


Figure 3. Diffraction and scattering of sound into shadow zone.

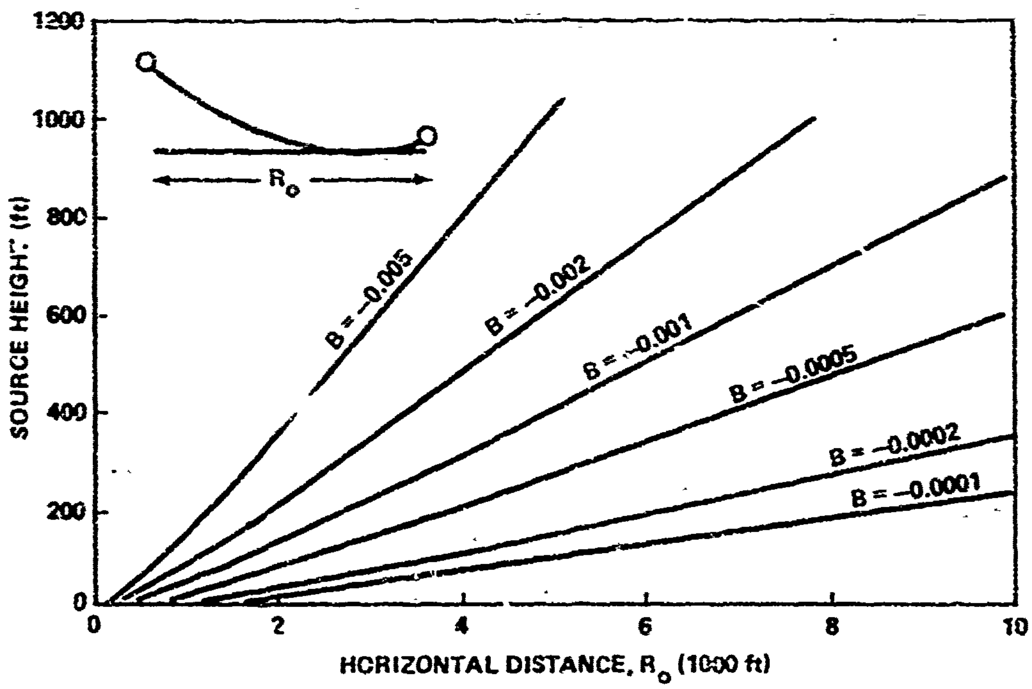


Figure 4. Horizontal distance, R_o, from source to shadow boundary as a function of source height and logarithmic sound velocity gradient, B. Height of observation point is 5 feet.

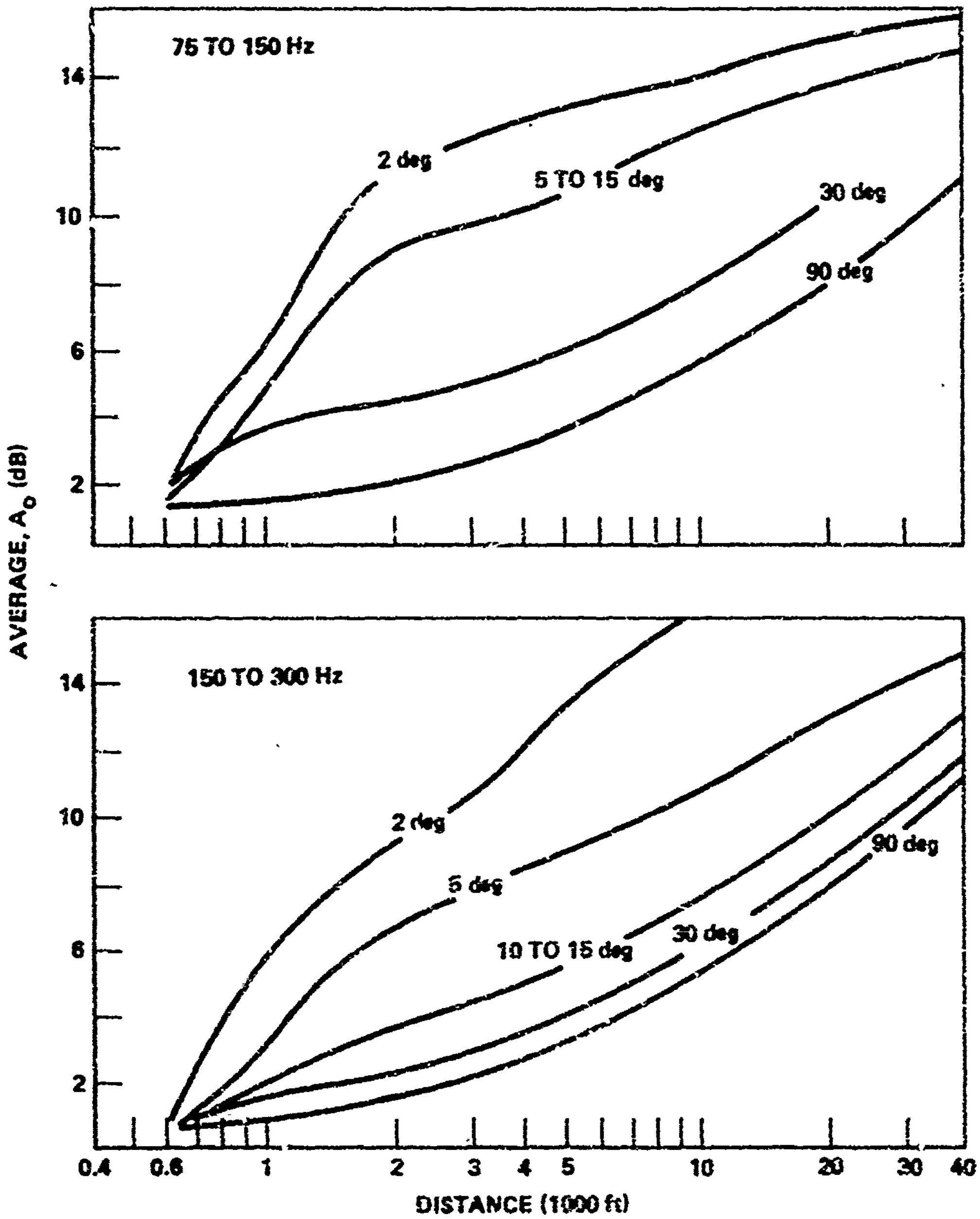


Figure 5. Average residual attenuation due to turbulence as a function of distance from source and source elevation angle.

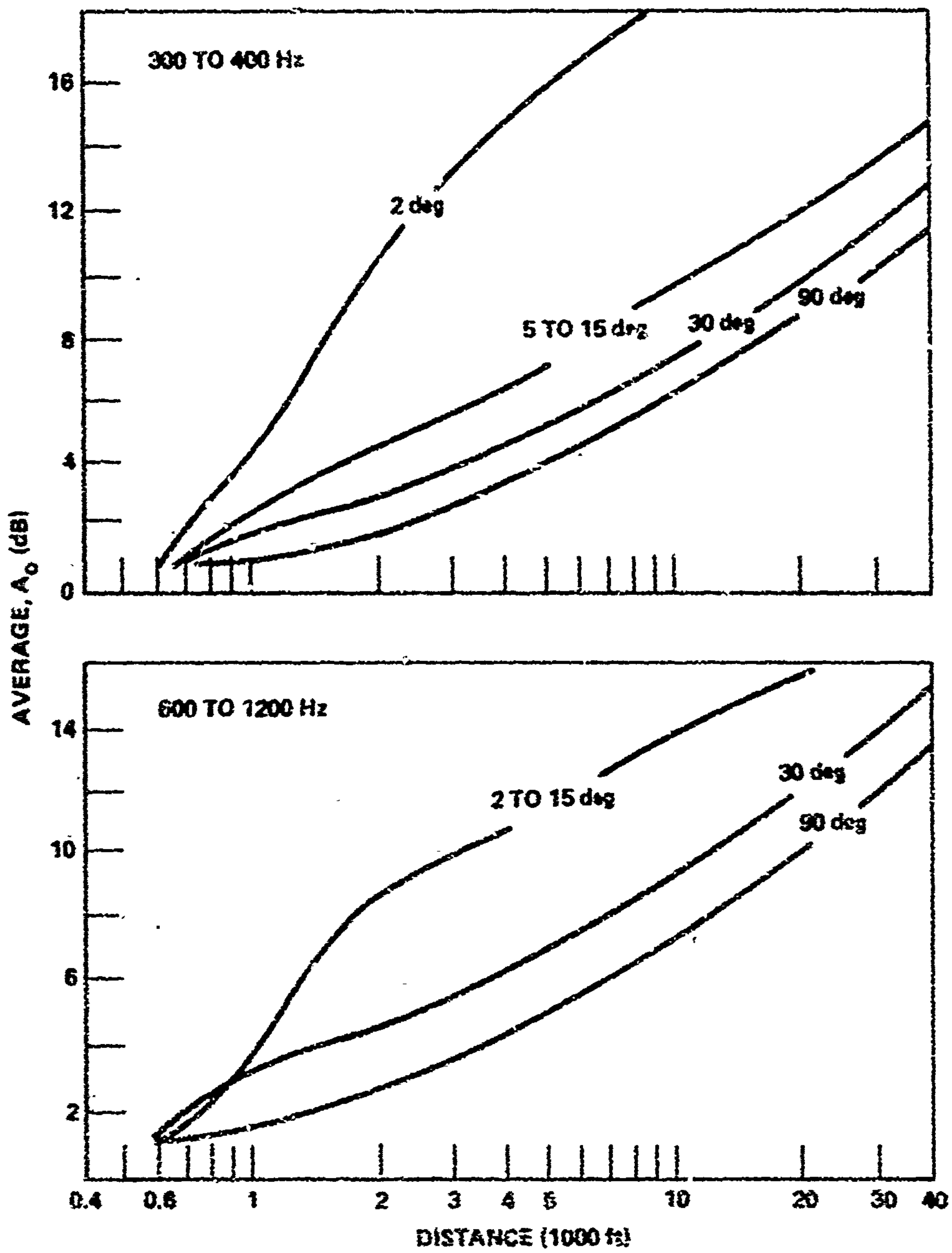


Figure 5. Continued

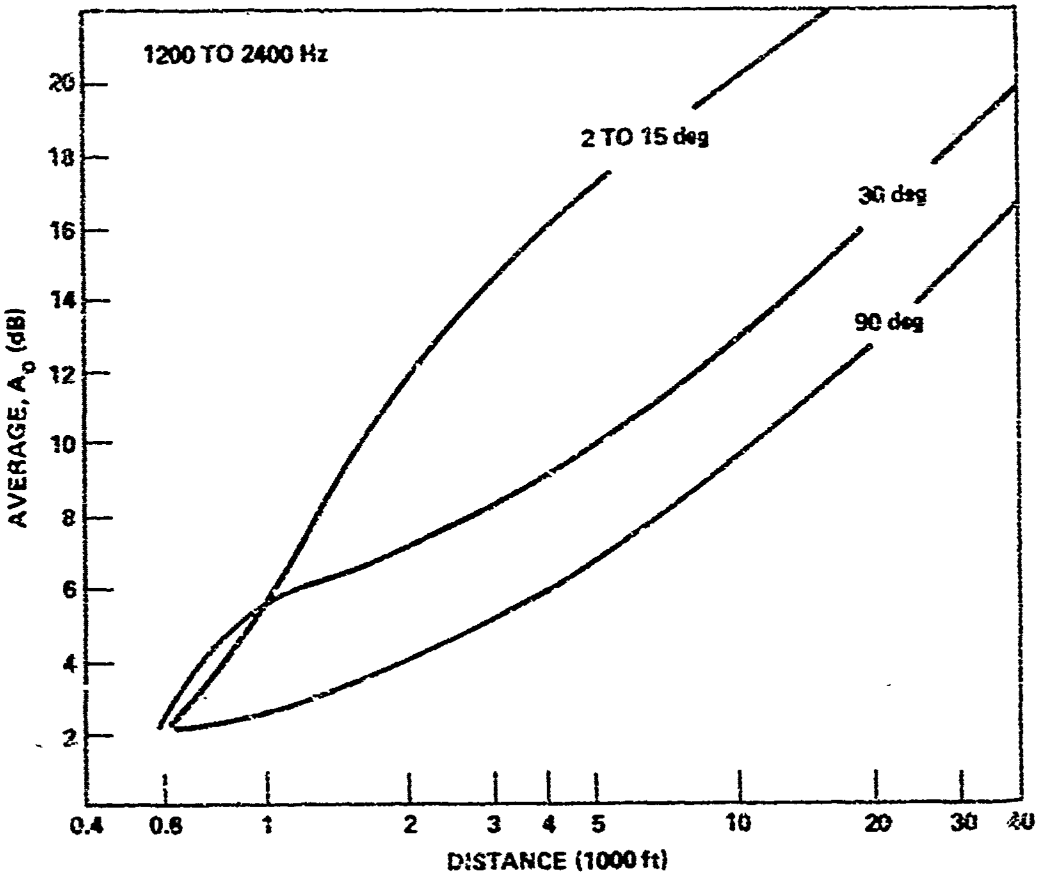


Figure 5. Concluded

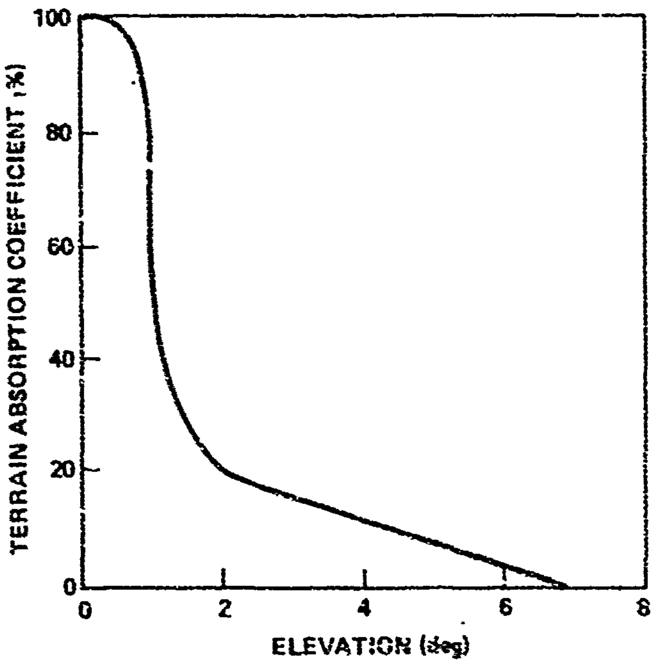


Figure 6. Terrain absoprtion coefficient versus elevation angle.

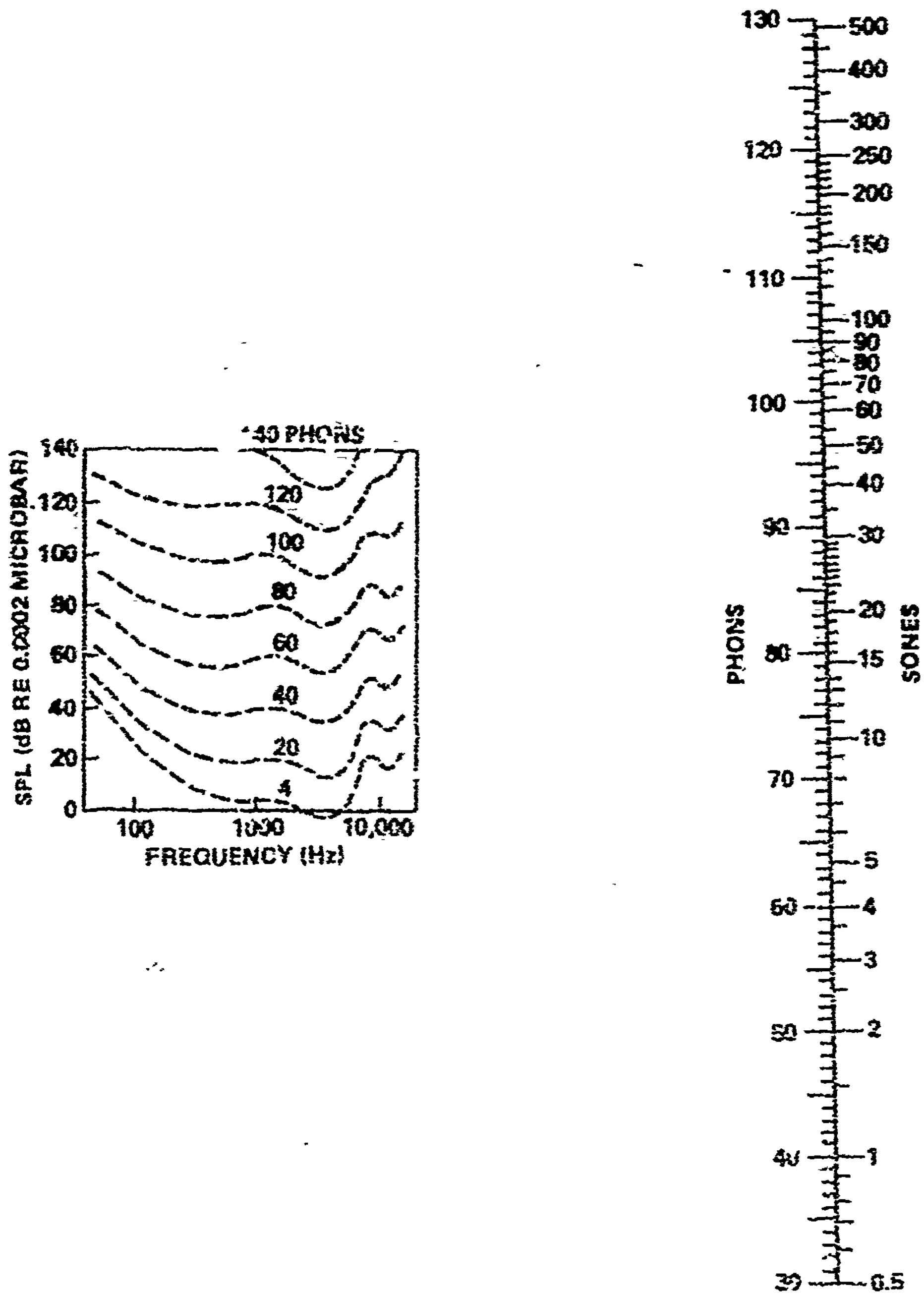


Figure 7. Equal-loudness-level contours.

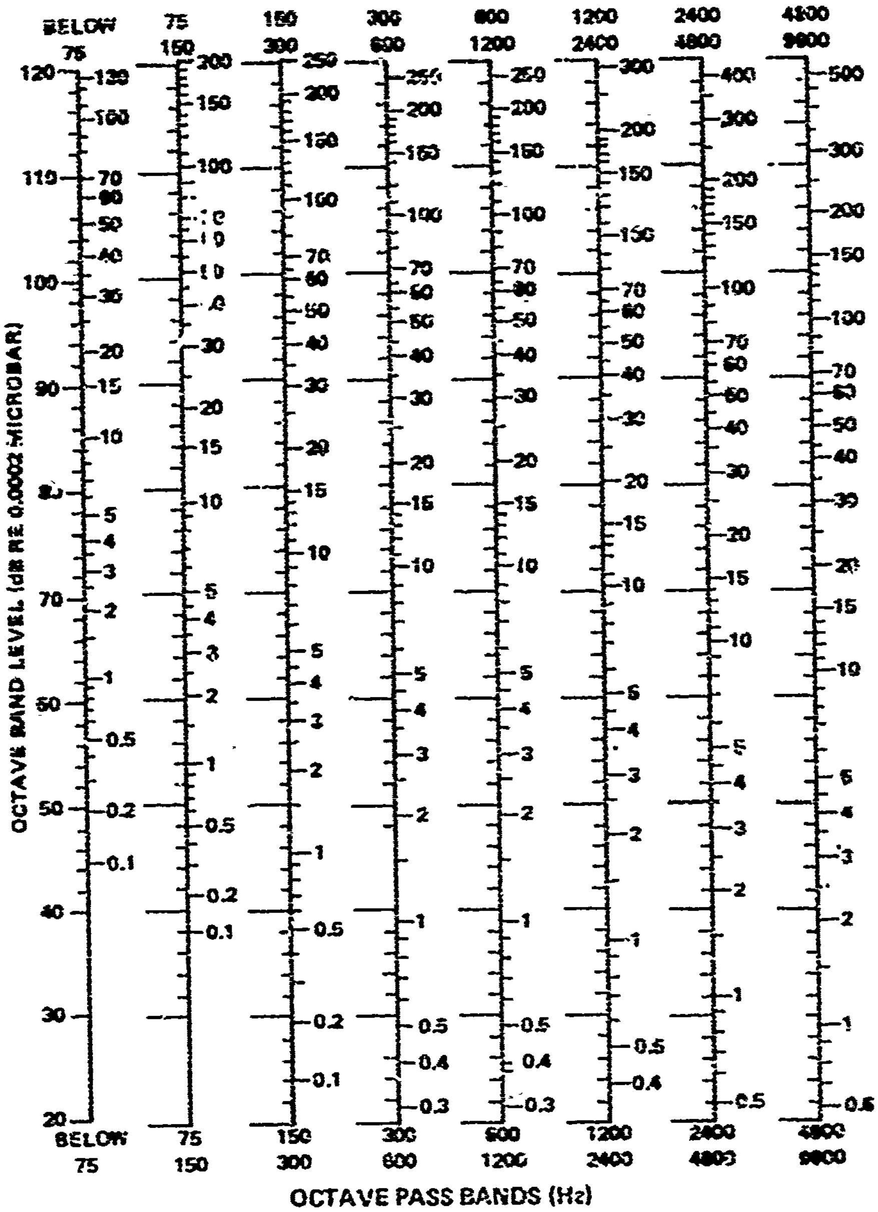


Figure 8. SPL to sones [4].

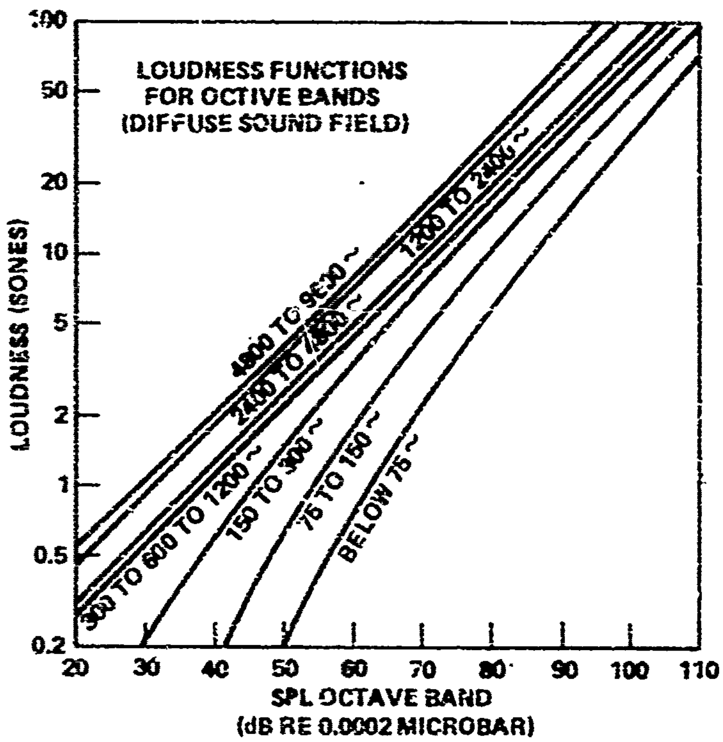


Figure 8. Concluded

Appendix A. WIND-SOUND ANGLE (PHI)

The figures and tables in this report contain an explanation on the calculation of the wind-sound angle, phi, a critical angle in the determination of the shadow region. All tables and graphs used in the model are included in this report.

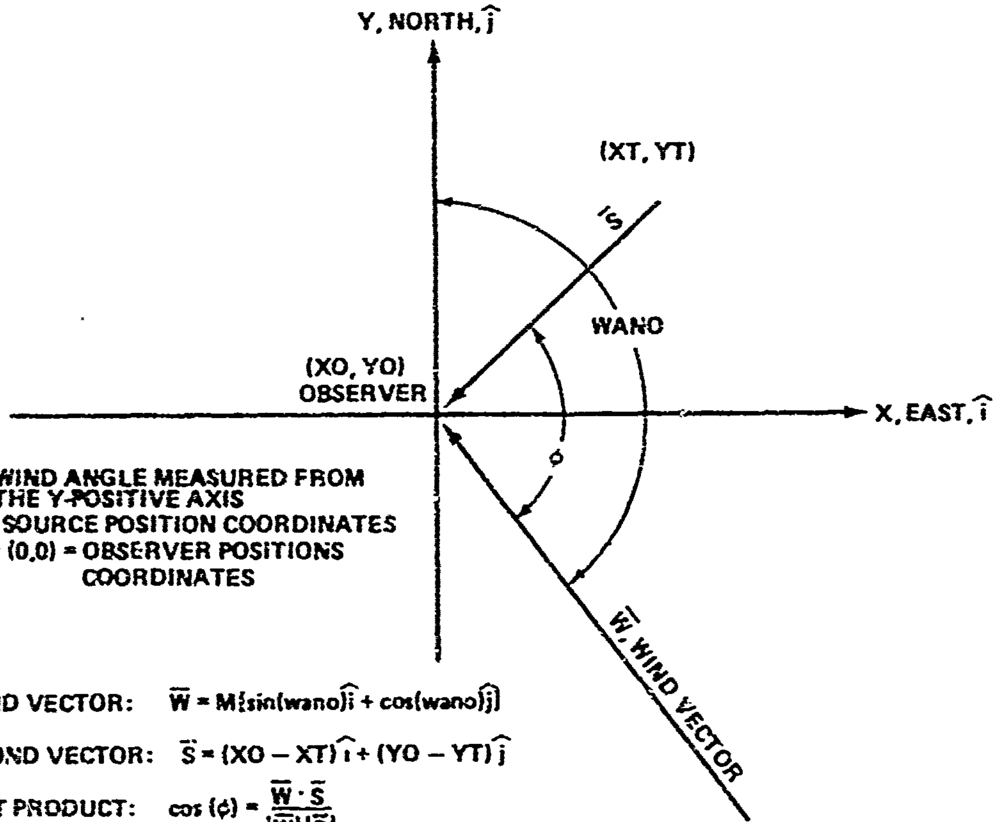
Procedure:

1) Express the wind vector, $\overline{W}$, with magnitude, M, and direction wano (wind angle measured clockwise from the Y-positive axis-north).

2) Express the sound vector, $\overline{S}$, in terms of direction of sound propagation from source to observer.

3) Change the two vectors to unit vectors and take their dot product.

4) Take the arc cosine of the dot product to find the wind-sound angle, phi.



WANO = WIND ANGLE MEASURED FROM THE Y-POSITIVE AXIS
XT, YT = SOURCE POSITION COORDINATES
XO, YO = (0,0) = OBSERVER POSITIONS COORDINATES

1) WIND VECTOR: $\overline{W} = M[\sin(wano)\hat{i} + \cos(wano)\hat{j}]$

2) SOUND VECTOR: $\overline{S} = (XO - XT)\hat{i} + (YO - YT)\hat{j}$

3) DOT PRODUCT: $\cos(\phi) = \dfrac{\overline{W} \cdot \overline{S}}{|\overline{W}||\overline{S}|}$

4) THE WIND-SOUND ANGLE, ϕ: $\phi = \arccos\left[\dfrac{\overline{W} \cdot \overline{S}}{|\overline{W}|\ |\overline{S}|}\right]$

Appendix B. COMPUTER PROGRAM

The main program acts as a calling program and an output program, and few calculations are carried on in this part. Most of the critical task calculations are carried on in the subroutines. There is a great deal of data in terms of arrays representing either graphs or tables, and a large percentage of the data is read in by assignment statements. Besides data representing graphs and tables, there are also certain inputs to describe the conditions for detection:

1) DELTAT - value of the temperature gradient (constant-°F/1000 feet)
2) TO - temperature on the ground
3) T - temperature at height of target
4) DT - delta time - time incremental value
5) WANO - wind angle measured from the north direction (y-positive)
6) FEET - height where WIND is measured (not lower than 3 feet)
7) WIND - wind magnitude at height FEET
8) RH - relative humidity
9) L - picks out terrain type (4 types are available)
10) XT - x-coordinate of target position
11) YT - y-coordinate of target position
12) ZT - z-coordinate of target position
13) VX - x-coordinate of target vector velocity
14) VY - y-coordinate of target vector velocity
15) VZ - z-coordinate of target vector velocity
16) AX - x-component of target vector acceleration
17) AY - y-component of target vector acceleration
18) AZ - z-component of target vector acceleration.

Discretion should be used when inputting target positions because there is a time limit on the flight path. This time limit could be changed but, in its present form, 120 seconds is the time limit for the aircraft to fly into detection range. This is true because the aircraft does not necessarily have to fly into detection range. If it does not, the probability of aural detection will not reach 1.0, and the output along with this probability will be "AIRCRAFT DID NOT FLY WITHIN DETECTION RANGE." Therefore this time limit, which is changeable, is a fact that must be remembered when inputting initial conditions.

There are 19 subprograms in the model plus a plotting routine. Such a large number is used because the programmer preferred an uncluttered main program and an orderly assignment of tasks to a subprogram instead of grouping several tasks to one subroutine. The following is a list of the subroutines used and an explanation of their function:

Subroutine	Called From	Function or Contribution
ACCUML	MAIN	Calculates loudness (sones)
ALPH	MAIN	Calculates atmospheric attenuation
ALPHO	SHADOW	Calculates residual attenuation
ALOCAT	MAIN	Allows aspect angles (signatures)
AVEAO	ALPHO	Locates the value of residual attenuation
DEEBEE	ACCUML	Calculates probability
DINT	ALPH	Mathematical subroutine
DVDINT	ALPH	Mathematical subroutine
FLIGHT	MAIN	Calculates new target positions
FIG	ALPHO	Calculates whether an observer is in a sound shadow
INTEP	FIG	Interpolates
INTERP	AVEAO	Interpolates
ORDER	ACCUML	Ranks orders
RELPOS	MAIN	Calculates elevation angle, azimuth angle, and range
SHADOW	MAIN	Calculates by calling other subroutines, residual attenuation
TAB	FUNCTION	Allows a 4-dimensioned array
TABLE1	ALPHO	Table look-up
VEG	MAIN	Calculates terrain absorption
WEED	MAIN	Calculates phi, the wind-sound angle, W_{30}, magnitude of wind at 30 feet.

Several subroutines were used from an existing model [i]. The program will accept target signatures for five frequency bands that are critical ones for an airborne source. These frequency bands are: 75 to 150, 150 to 300, 300 to 600, 600 to 1200, and 1200 to 2400 hertz. The frequencies used in calculations are the geometric mean frequencies of the bands. Velocity and acceleration units are divided into vector

components. Therefore the signs of the velocity and acceleration components must be remembered in relation with the observer. If the target is at positive position coordinates, negative velocity coordinates must be inputted for the aircraft to fly over the observer. The same applies to acceleration coordinates also. Figure B-1 shows how the geometry of the program is set up.

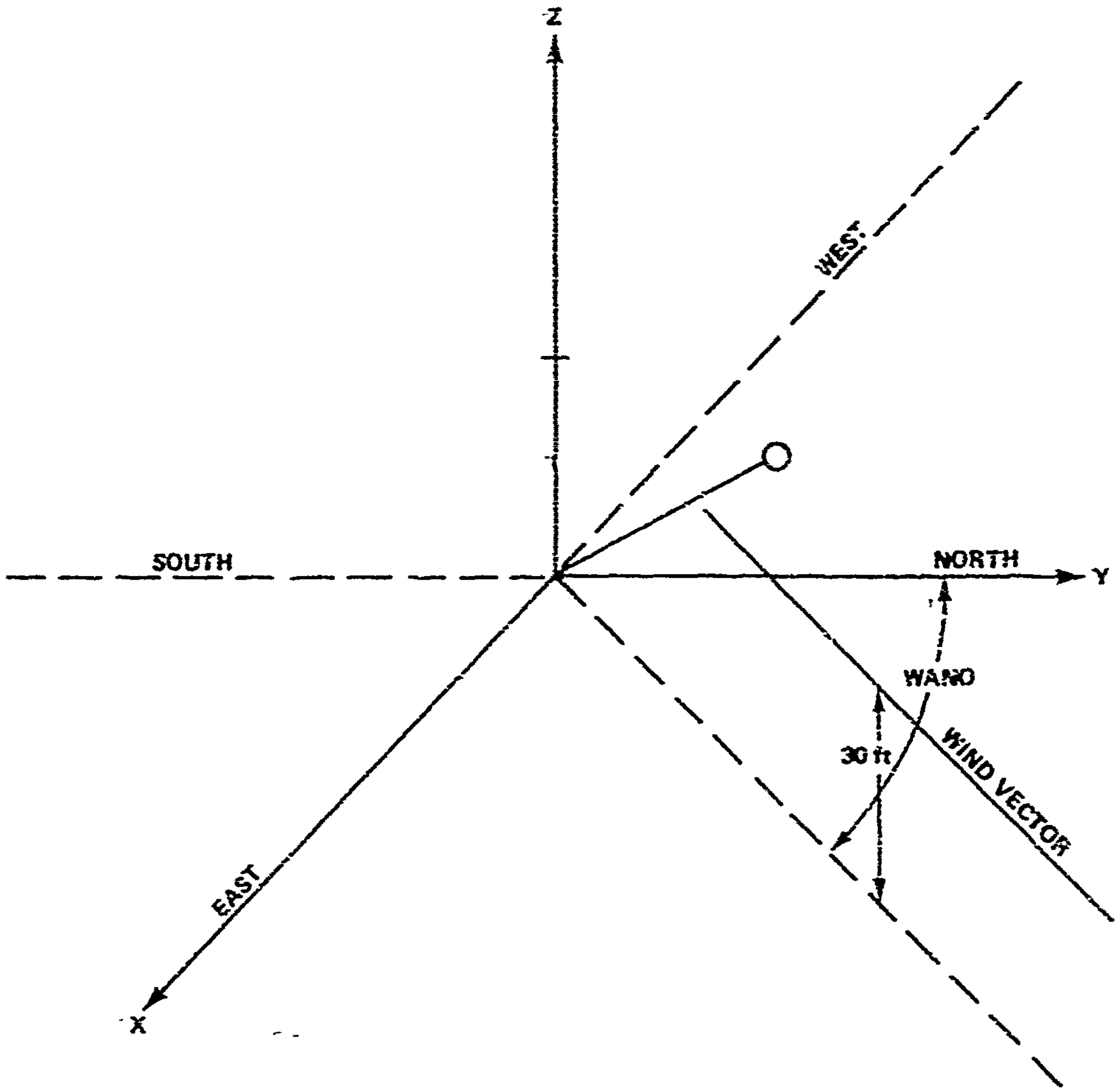


Figure B-1. Geometry of model - phi is the wind-sound angle at height 30 feet. Consider the wind angle wano as the angle of the wind vector with the Y-axis. Y-axis corresponds to north, X-axis east-west, etc.

```
UDTDA,T454.
ACCT(PN=DON,PBC=3287D10100,CC=7700,OP=A2,JN=0000)
FTN(L=0,PL=20000)
LGO.
EXIT.
000000000000000000000000
      PROGRAM MAIN (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION XTAR(50),YTAR(50),ZTAR(50)
      COMMON ZAA(8),SIG(5,10,8),AMB(5),DO(10),C(6),EL(6),YX(17),KK
      COMMON FIGS(6,6),Z(6),AC(5,4),E(4),EE(4),SONES(5,11),KTER,DELTAT,T
      COMMON TO,PIE,WANG,WIND,FEET,RH,AX,AY,AZ,XT,YT,ZT,VX,VY,VZ
      COMMON/DIMCOM/TABDIM (120)
      NAMELIST/DON/TABDIM
C     N TELLS HOW MANY SIGNATURES ARE TO BE READ IN
C     N SHOULD NOT EXCEED 10--SEE DIMENSION STATEMENTS
      N=5
C     TO CALCULATE TERRAIN ATTENUATION
C     K . . . 1-OPEN AREA
C     K . . . 2-18 INCH GRASS
C     K . . . 3-LIGHTLY TREED
C     K . . . 4-FOREST
C     AT IS THE TERRAIN ATTENUATION COEFFICIENT
      K=4
      KTER=K
C     VARIOUS CONDITIONS
      DELTAT=-.5
C     TEMPERTURE T MEASURED AT ZT
      T=38.
      TO=60.
      PIE=3.1415926536
      WIND=50.
      FEET=15.
      WANG=270.
      RH=.40
      AX=0.
      AY=0.
      AZ=0.
      VX=-338.98
      VY=0.
      VZ=0.
C     KK --PICKS OUT THE CHOSEN AIRCRAFT FROM SIGNATURE BANK
      KK=1
C SIG(I,J,K) I--PICKS OUT FREQUENCY
C             J--A/C TYPE
C             K--PICKS OUT ASPECT ANGLE
      READ (5,21)(((SIG(I,J,K),K=1,5),I=1,5),J=1,N)
      READ (5,10) (DO(I),I=1,N)
      READ (5,21) (AMB(I),I=1,5)
      READ (5,21)(ZAA(I),I=1,5)
      READ (5,11) (C(I),I=1,6)
      READ (5,11) (EL(I),I=1,6)
      READ (5,20) (YX(I),I=1,17)
      READ (5,11) ((FIGS(II,JJ),II=1,6),JJ=1,6)
      READ (5,11) (Z(I),I=1,6)
      READ (5,DON)
      READ (5,21) ((AC(I,J),I=1,5),J=1,4)
      READ (5,22) (E(I),I=1,4)
      READ (5,22) (EE(I),I=1,4)
      READ (5,21)((SONES(I,J),I=1,5),J=1,11)
   10 FORMAT(8F10.0)
   11 FORMAT(6F10.0)
   12 FORMAT(7F10.0)
   20 FORMAT(8F10.0/8F10.0/F10.0)
```

```
   21 FORMAT(5F10.0)
   22 FORMAT(4F10.0)
      DO 50 K=1,5
      ZTAR(K)=500.*K
      DO 50 J=1,6
      YTAR(J)=3280.84*(J-1)
      DO 50 I=1,8
      XTAR(I)=3280.84*(I-1)
      XT=XTAR(I)
      YT=YTAR(J)
      ZT=ZTAR(K)
      CALL WHOLE
   50 CONTINUE
      STOP
      END
      SUBROUTINE WHOLE
      DIMENSION FO(5),A(5,17,6),SPL(5),SPLS(5),AO(5),AT(5),AH(5),AA(5)
      DIMENSION DELADO(5)
      COMMON ZAA(8),SIG(5,10,8),AMB(5),DO(10),C(6),EL(6),YX(17),KK
      COMMON FIGS(6,6),Z(6),AC(5,4),E(4),EE(4),SONES(5,11),KTER,DELTAT,T
      COMMON TO,PIE,WANO,WIND,FEET,PH,AX,AY,AZ,XT,YT,ZT,VX,VY,VZ
      COMMON/DIMCOM/TABDIM (120)
      TIME=0.
      DT=1.
      L=0
      F=53.
      DO 1 I=1,5
      F=2.0*F
    1 FO(I)=F
C     OBSERVER AND TARGET INFORMATION
      XO=0.
      YO=0.
      ZO=5.
C
C     CALCULATE ATTENUIATION DUE TO HUMIDITY
C
      CALL ALPH(RH,T,AH,FO)
      DO 55 I=1,5
      DO 55 J=1,17
      DO 55 M=1,6
   55 A(I,J,M)=0.
      A(1,1,1)=1.5
      A(1,2,1)=3.3
      A(1,1,2)=1.5
      A(1,1,3)=1.5
      A(1,1,4)=1.5
      A(1,8,1)=12.8
      A(1,9,1)=13.3
      A(1,10,1)=13.6
      A(1,11,1)=13.8
      A(1,12,1)=13.9
      A(1,13,1)=14.0
      A(1,14,1)=14.0
      A(1,15,1)=15.1
      A(1,16,1)=15.5
      A(1,17,1)=15.8
      A(1,10,2)=A(1,10,3)=A(1,10,4)=11.4
      A(1,11,2)=A(1,11,3)=A(1,11,4)=11.8
      A(1,12,2)=A(1,12,3)=A(1,12,4)=12.0
      A(1,13,2)=A(1,13,3)=A(1,13,4)=12.3
      A(1,14,2)=A(1,14,3)=A(1,14,4)=12.4
      A(1,15,2)=A(1,15,3)=A(1,15,4)=14.0
      A(1,16,2)=A(1,16,3)=A(1,16,4)=14.5
      A(1,17,2)=A(1,17,3)=A(1,17,4)=14.8
```

```
A(2,1,1)=A(2,1,2)=.7
A(2,2,1)=2.5
A(2,2,2)=1.1
A(2,1,3)=A(2,1,4)=.7
A(2,2,3)=A(2,2,4)=.9
A(2,1,5)=A(2,1,6)=.7
A(2,2,6)=.8
A(2,10,1)=14.2
A(2,11,1)=15.0
A(2,12,1)=15.6
A(2,13,1)=15.8
A(2,14,1)=16.0
A(2,15,1)=17.0
A(2,16,1)=17.3
A(2,17,1)=17.5
A(2,10,2)=9.4
A(2,11,2)=10.0
A(2,12,2)=10.2
A(2,13,2)=10.4
A(2,14,2)=10.5
A(2,15,2)=12.9
A(2,16,2)=14.0
A(2,17,2)=14.8
A(2,10,3)=A(2,10,4)=6.2
A(2,11,3)=A(2,11,4)=6.7
A(2,12,3)=A(2,12,4)=7.0
A(2,13,3)=A(2,13,4)=7.4
A(2,14,3)=A(2,14,4)=7.8
A(2,15,3)=A(2,15,4)=10.1
A(2,16,3)=A(2,16,4)=12.0
A(2,17,3)=A(2,17,4)=13.0
A(2,10,5)=4.8
A(2,11,5)=5.3
A(2,13,5)=6.0
A(2,14,5)=6.1
A(2,15,5)=8.8
A(2,16,5)=10.3
A(2,17,5)=11.8
A(2,12,5)=5.8
A(2,10,6)=4.0
A(2,11,6)=4.4
A(2,12,6)=5.0
A(2,13,6)=5.2
A(2,14,6)=5.8
A(2,15,6)=8.0
A(2,16,6)=9.8
A(2,17,6)=11.0
A(3,10,1)=16.4
A(3,11,1)=17.2
A(3,12,1)=18.0
A(3,13,1)=18.2
A(3,14,1)=18.4
A(3,15,1)=19.3
A(3,16,1)=20.0
A(3,17,1)=21.0
A(3,10,2)=A(3,10,3)=A(3,10,4)=8.0
A(3,11,2)=A(3,11,3)=A(3,11,4)=8.4
A(3,12,2)=A(3,12,3)=A(3,12,4)=9.0
A(3,13,2)=A(3,13,3)=A(3,13,4)=9.6
A(3,14,2)=A(3,14,3)=A(3,14,4)=10.0
A(3,15,2)=A(3,15,3)=A(3,15,4)=12.0
A(3,16,2)=A(3,16,3)=A(3,16,4)=14.0
A(3,17,2)=A(3,17,3)=A(3,17,4)=14.8
```

```
A(3,10,5)=5.9
A(3,11,5)=6.3
A(3,12,5)=6.3
A(3,13,5)=7.2
A(3,14,5)=7.7
A(3,15,5)=9.8
A(3,16,5)=11.8
A(3,17,5)=12.4
A(3,10,6)=4.8
A(3,11,6)=5.2
A(3,12,6)=5.8
A(3,13,6)=6.0
A(3,14,6)=6.3
A(3,15,6)=9.0
A(3,16,6)=10.2
A(3,17,6)=11.8
A(4,10,1)=A(4,10,2)=A(4,10,3)=A(4,10,4)=12.0
A(4,11,1)=A(4,11,2)=A(4,11,3)=A(4,11,4)=12.6
A(4,12,1)=A(4,12,2)=A(4,12,3)=A(4,12,4)=13.3
A(4,13,1)=A(4,13,2)=A(4,13,3)=A(4,13,4)=13.8
A(4,14,1)=A(4,14,2)=A(4,14,3)=A(4,14,4)=14.0
A(4,15,1)=A(4,15,2)=A(4,15,3)=A(4,15,4)=15.8
A(4,16,1)=A(4,16,2)=A(4,16,3)=A(4,16,4)=16.7
A(4,17,1)=A(4,17,2)=A(4,17,3)=A(4,17,4)=17.0
A(4,10,5)=7.8
A(4,11,5)=8.0
A(4,12,5)=8.2
A(4,13,5)=8.9
A(4,14,5)=9.8
A(4,15,5)=12.0
A(4,16,5)=13.0
A(4,17,5)=14.5
A(4,10,6)=5.9
A(4,11,6)=6.2
A(4,12,6)=6.4
A(4,13,6)=7.0
A(4,14,6)=7.4
A(4,15,6)=10.0
A(4,16,6)=11.8
A(4,17,6)=12.3
A(5,11,1)=A(5,11,2)=A(5,11,3)=A(5,11,4)=18.5
A(5,12,1)=A(5,12,2)=A(5,12,3)=A(5,12,4)=19.3
A(5,13,1)=A(5,13,2)=A(5,13,3)=A(5,13,4)=19.9
A(5,14,1)=A(5,14,2)=A(5,14,3)=A(5,14,4)=20.1
A(5,15,1)=A(5,15,2)=A(5,15,3)=A(5,15,4)=23.5
A(5,16,1)=A(5,16,2)=A(5,16,3)=A(5,16,4)=24.0
A(5,17,1)=A(5,17,2)=A(5,17,3)=A(5,17,4)=25.0
A(5,11,5)=11.4
A(5,12,5)=12.0
A(5,13,5)=12.9
A(5,14,5)=13.5
A(5,15,5)=16.3
A(5,16,5)=18.4
A(5,17,5)=20.0
A(5,11,6)=8.0
A(5,12,6)=8.8
A(5,13,6)=9.2
A(5,14,6)=9.8
A(5,15,6)=13.9
A(5,16,6)=15.2
A(5,17,6)=16.4
A(1,3,1)=4.8
A(1,4,1)=5.25
```

A(1,5,1)=6.1
A(1,6,1)=11.3
A(1,7,1)=12.0
A(1,2,2)=2.5
A(1,3,2)=3.0
A(1,4,2)=3.8
A(1,5,2)=4.5
A(1,6,2)=9.0
A(1,7,2)=9.9
A(1,8,2)=10.25
A(1,9,2)=10.8
A(1,2,3)=2.5
A(1,3,3)=3.0
A(1,4,3)=3.8
A(1,5,3)=4.5
A(1,6,3)=9.0
A(1,7,3)=9.9
A(1,8,3)=10.25
A(1,9,3)=10.8
A(1,5,4)=3.9
A(1,6,4)=4.5
A(1,7,4)=5.0
A(1,8,4)=5.5
A(1,9,4)=6.0
A(1,10,4)=6.25
A(1,1,5)=1.5
A(1,2,5)=1.6
A(1,3,5)=1.7
A(1,4,5)=1.7
A(1,5,5)=1.8
A(1,6,5)=2.0
A(1,7,5)=2.6
A(1,8,5)=3.2
A(1,9,5)=3.8
A(2,3,1)=4.0
A(2,4,1)=4.8
A(2,5,1)=5.9
A(2,6,1)=9.2
A(2,7,1)=10.6
A(2,8,1)=12.0
A(2,9,1)=13.2
A(2,3,4)=1.0
A(2,4,4)=1.5
A(2,5,4)=1.7
A(2,6,4)=2.5
A(2,7,4)=3.2
A(2,8,4)=3.9
A(2,9,4)=4.2
A(2,3,2)=2.0
A(2,4,2)=2.35
A(2,5,2)=3.0
A(2,6,2)=6.9
A(2,7,2)=7.7
A(2,8,2)=8.25
A(2,9,2)=8.9
A(2,1,5)=.8
A(2,2,5)=.9
A(2,3,5)=1.0
A(2,4,5)=1.0
A(2,5,5)=1.0
A(2,6,5)=1.7
A(2,7,5)=2.4
A(2,8,5)=3.0
A(2,9,5)=3.65
A(2,3,3)=1.0
A(2,4,3)=1.5
A(2,5,3)=2.0
A(2,6,3)=3.8
A(2,7,3)=4.5
A(2,8,3)=5.2
A(2,9,3)=5.8
A(3,1,1)=.8
A(3,2,1)=2.2
A(3,3,1)=3.3
A(3,4,1)=4.0
A(3,5,1)=4.6
A(3,6,1)=10.5
A(3,7,1)=13.4
A(3,8,1)=15.0
A(3,9,1)=16.0
A(3,6,4)=3.1
A(3,7,4)=4.0
A(3,8,4)=4.8
A(3,9,4)=5.4
A(3,1,5)=.8
A(3,2,5)=.8
A(3,3,5)=.9
A(3,4,5)=1.0
A(3,5,5)=1.0
A(3,6,5)=2.0
A(3,7,5)=3.0
A(3,8,5)=3.8
A(3,9,5)=4.3
A(3,1,2)=.8
A(3,2,2)=1.0
A(3,3,2)=2.0
A(3,4,2)=2.4
A(3,5,2)=2.6
A(3,6,2)=4.8
A(3,7,2)=6.0
A(3,8,2)=6.8
A(3,9,2)=7.4
A(3,1,4)=.8
A(3,2,4)=1.0
A(3,3,4)=1.2
A(3,4,4)=1.8
A(3,5,4)=2.0
A(4,5,1)=4.0
A(4,6,1)=9.0
A(4,7,1)=10.
A(4,8,1)=11.0
A(4,9,1)=11.6
A(4,5,4)=3.6
A(4,6,4)=5.0
A(4,7,4)=5.9
A(4,8,4)=6.5
A(4,9,4)=7.3
A(4,5,2)=4.0
A(4,6,2)=9.0
A(4,7,2)=10.0
A(4,8,2)=11.0
A(4,9,2)=11.6
A(4,5,5)=1.8
A(4,6,5)=2.8
A(4,7,5)=3.9
A(4,8,5)=4.6

```
      A(4,9,5)=5.4
      A(4,5,3)=4.0
      A(4,6,3)=9.0
      A(4,7,3)=10.0
      A(4,8,3)=11.0
      A(4,9,3)=11.6
      A(5,1,1)=A(5,1,2)=A(5,1,3)=2.0
      A(5,2,1)=A(5,2,2)=A(5,2,3)=3.0
      A(5,3,1)=A(5,3,2)=A(5,3,3)=4.0
      A(5,4,1)=A(5,4,2)=A(5,4,3)=4.6
      A(5,5,1)=A(5,5,2)=A(5,5,3)=5.5
      A(5,6,1)=A(5,6,2)=A(5,6,3)=12.4
      A(5,7,1)=A(5,7,2)=A(5,7,3)=14.8
      A(5,8,1)=A(5,8,2)=A(5,8,3)=16.0
      A(5,9,1)=A(5,9,2)=A(5,9,3)=16.4
      A(5,10,1)=A(5,10,2)=A(5,10,3)=18.0
      A(5,5,4)=5.8
      A(5,6,4)=7.0
      A(5,7,4)=8.2
      A(5,8,4)=9.3
      A(5,9,4)=10.0
      A(5,10,4)=10.8
      A(5,1,5)=2.0
      A(5,2,5)=2.2
      A(5,3,5)=2.4
      A(5,4,5)=2.6
      A(5,5,5)=2.8
      A(5,6,5)=4.0
      A(5,7,5)=5.2
      A(5,8,5)=6.0
      A(5,9,5)=6.8
      A(5,10,5)=7.4
      KKK=0
      M=0
C     STARTING POINT
      WRITE (6,802) XT,YT,ZT
    2 TIME=TIME+DT
      CALL WEED(WANO,WIND,FEET,XT,YT,ZT,XO,YO,ZO,PHI,W30)
      CALL RELPOS(XO,YO,ZO,XT,YT,ZT,ZA,BETA,D,VX,VY,VZ)
      IF(BETA.LT.2.)GOTO 45
C     ******************************************************************
C     CALCUALTE ATTENUATION DUE TO TERRAIN TYPE
      K=KTER
      CALL VEG(BETA,D,AT,K,AC,E,EE)
C     ******************************************************************
      XX=XT-XO
C     ******************************************************************
C     CALCULATE ATTENUATION DUE TO TURBELENCE
      CALL SHADOW(XX,A,BETA,EL,D,DELTAT,T,YO,FIGS,AO,PHI,W30,XT,YT,ZT,XO
     1,YO,ZO,YX,C)
C     ******************************************************************
      IF(AO(1).EQ.(-1.))GOTO 45
      DO 3 I=1,5
    3 AA(I)=AH(I)*(D-DO(KK))/1000.+AO(I)+AT(I)
      DO 90 I=1,5
      CALL ALOCAT(I,KK,SIG,ZA,ZAA,REWARD)
      SPLS(I)=REWARD-20.*ALOG10(D/DO(KK))+3.-AA(I)
   90 CONTINUE
C     ******************************************************************
C     COMBINE SPL WITH AMBIENT
C     ******************************************************************
      DO 1000 I=1,5
      SPL(I)=10.**(SPLS(I)/10.)+10.**(AMB(I)/10.)
      SPL(I)=10.*ALOG10(SPL(I))
```

```
 1000 CONTINUE
C
C       CALCULATE PROBABILITY
        CALL ACCUML(SPL,AMB,SONES,VALUE,ABC)
C
        IF(ABC.EQ.0.)GOTO 45
        L=L+1
   35   IF(L/61*L.EQ.L)WRITE (6,800)
        IF(L/61*L.EQ.L)L=0
        WRITE (6,23) TIME, VALUE
        IF(VALUE.GE.,999999999)GOTO 19
   45   CALL FLIGHT(AX,AY,AZ,VX,VY,VZ,XT,YT,ZT,DT)
        IF(TIME.GE.120.)GOTO 50
        GOTO 2
   19   CALL RELPOS(XO,YO,ZO,XT,YT,ZT,ZA,BETA,D,VX,VY,VZ)
        KKK=2
        WRITE (6,28)
        WRITE (6,73) XT,YT,ZT
        WRITE (6,74) BETA
        WRITE (6,400) ZA
        WRITE (6,70) W30,PHI,TIME
        WRITE (6,100)
        K=KTER
        IF(K.EQ.1)WRITE (6,75)
        IF(K.EQ.2)WRITE (6,76)
        IF(K.EQ.3)WRITE (6,77)
        IF(K.EQ.4)WRITE (6,78)
        WRITE (6,14) (FO(I),AH(I),AO(I),AT(I),I=1,5)
        WRITE (6,100)
        WRITE (6,16) (FO(J),AA(J),SPLS(J),AMB(J),J=1,5)
        WRITE (6,29) D
        WRITE (6,100)
        XO=XT
        YO=YT
        ZO=ZT
        VS=1080.*SQRT((T+459.)/(TO+459.))
        DELAY=D/VS
        CALL FLIGHT(AX,AY,AZ,VX,VY,VZ,XD,YD,ZD,DELAY)
        CALL RELPOS(XO,YO,ZO,XD,YD,ZD,ZA,BETA,DD,VX,VY,VZ)
        WRITE (6,801) DELAY,DD
        DT=6.
        TIME=TIME+DT
        CALL FLIGHT(AX,AY,AZ,VX,VY,VZ,XT,YT,ZT,DT)
        CALL RELPOS(XO,YO,ZO,XT,YT,ZT,ZA,BETA,D,VX,VY,VZ)
        WRITE (6,100)
        WRITE (6,73) XT,YT,ZT
        WRITE (6,74) BETA
        WRITE (6,400) ZA
        WRITE (6,15) TIME,D
   50   CONTINUE
        IF(KKK.EQ.0)WRITE (6,200)
C
   14   FORMAT(1X,6H FREQ=,F10.2,2X,4H AH=,F8.3,12H DB/1000. FT,2X,4H AO=,
       6F8.3,2X,4H AT=,F8.3)
   15   FORMAT(1X,35H VISUAL DETECTION OF TARGET AT TIME,F8.2,9H AT RANGE,
       6F10.2)
   16   FORMAT(1X,6H FREQ=,F10.2,2X,19H TOTAL ATTENUATION=,F8.3,2X,5H SPL=
       6,F10.3,2X,9H AMBIENT=,F10.3)
   23   FORMAT(1X,F7.2,11X,F10.5)
   28   FORMAT(1H1)
   29   FORMAT(1X,31H OBSERVER HEARS TARGET AT RANGE,F10.2)
   70   FORMAT(1X,5H W30=,F6.2,5H PHI=,F6.2,6H TIME=,F6.2)
   73   FORMAT(1X,6H XT=,F8.2,4H YT=,F8.2,6H ZT=,F8.2)
```

```
   74 FORMAT(1X,6H BETA=,F6.2)
   75 FORMAT(1X,18H TERRAIN-OPEN AREA)
   76 FORMAT(1X,22H TERRAIN-18 INCH GRASS)
   77 FORMAT(1X,22H TERRAIN-LIGHTLY TREED)
   78 FORMAT(1X,15H TERRAIN-FOREST)
  100  FORMAT(1X,///)
  200 FORMAT(1X,42H AIRCRAFT DID NOT FLY WITHIN HEARING RANGE)
  400 FORMAT(1X,15H AZIMUTH ANGLE=,F10.2)
  800 FORMAT(1H1,7X,5H TIME,5X,36H PROBABILITY OF AUDITORY DETECTION)
  801 FORMAT(1X,14H DELAY TIME IS,F4.0,32H SECONDS, TARGET IS NOW AT RAN
     9GE,F9.2)
  802 FORMAT(1H1,2X,5H TIME,5X,36H PROBABILITY OF AUDITORY DETECTION,10X
     6,15H STARTING POINT,3X,4H XT=,F8.2,4H YT=,F8.2,4H ZT=,F8.2)
C
      RETURN
      END
      SUBROUTINE ACCUML(SPL,AMB,SONES,PROB,ABC)
      DIMENSION SONES(5,11),SPL(5),AMB(5),S(5),SS(5),DEC(11)
      DATA DEC/20.,30.,40.,50.,60.,70.,80.,90.,100.,110.,120./
      ABC=1.
      SAMB=SNL=0.
      DO 15 I=1,5
      K=0
      IF(SPL(I).LT.20..OR.SPL(I).GT.120.)GOTO 20
      DO 15 J=1,10
      IF(SPL(I).GE.DEC(J).AND.SPL(I).LT.DEC(J+1))GOTO 10
      GOTO 15
   10 S(I)=((SPL(I)-DEC(J))/(DEC(J+1)-DEC(J)))*(SONES(I,J+1)-SONES(I,J))
     5+SONES(I,J)
   15 CONTINUE
      CALL ORDER(S)
      GOTO 25
   20 ABC=0.
      RETURN
   25 CONTINUE
      DO 35 I=1,5
      IF(AMB(I).LT.20..OR.AMB(I).GT.120.)GOTO 20
      DO 35 J=1,10
      IF(AMB(I).GE.DEC(J).AND.AMB(I).LT.DEC(J+1))GOTO 30
      GOTO 35
   30 SS(I)=((AMB(I)-DEC(J))/(DEC(J+1)-DEC(J)))*(SONES(I,J+1)-SONES(I,J)
     6)+SONES(I,J)
   35 CONTINUE
      CALL ORDER(SS)
      DO 40 I=1,5
      SAMB=SS(I)+SAMB
      SNL=S(I)+SNL
   40 CONTINUE
      CALL DEEBEE(SNL,SAMB,PROB,ABC)
      RETURN
      END
      SUBROUTINE ALPH(RH,T,AH,FO)
      DIMENSION R(17,11),W(17,11),FO(5),AH(5),TT(17),FI(5)
      BB=20.0
      DO 1 I=1,17
      TT(I)=BB
    1 BB=BB+5.0
      DO 2 I=1,17
      R(I,1)=.1
      R(I,2)=.15
      R(I,3)=.2
      R(I,4)=.3
      R(I,5)=.4
```

```
      R(I,6)=.5
      R(I,7)=.6
      R(I,8)=.7
      R(I,9)=.8
      R(I,10)=.9
    2 R(I,11)=1.0
      W(1,1)=.3
      W(1,2)=.42
      W(1,3)=.57
      W(1,4)=.85
      W(1,5)=1.125
      W(1,6)=1.4
      W(1,7)=1.7
      W(1,8)=1.9
      W(1,9)=2.125
      W(1,10)=2.5
      W(1,11)=2.7
      W(2,1)=.36
      W(2,2)=.53
      W(2,3)=.7
      W(2,4)=1.1
      W(2,5)=1.45
      W(2,6)=1.70
      W(2,7)=2.1
      W(2,8)=2.48
      W(2,9)=2.80
      W(2,10)=3.1
      W(2,11)=3.5
      W(3,1)=.46
      W(3,2)=.68
      W(3,3)=.89
      W(3,4)=1.3
      W(3,5)=1.75
      W(3,6)=2.1
      W(3,7)=2.6
      W(3,8)=3.05
      W(3,9)=3.5
      W(3,10)=3.9
      W(3,11)=4.3
      W(4,1)=.55
      W(4,2)=.81
      W(4,3)=1.1
      W(4,4)=1.6
      W(4,5)=2.07
      W(4,6)=2.7
      W(4,7)=3.3
      W(4,8)=3.8
      W(4,9)=4.2
      W(4,10)=4.8
      W(4,11)=5.2
      W(5,1)=.67
      W(5,2)=.98
      W(5,3)=1.3
      W(5,4)=1.9
      W(5,5)=2.6
      W(5,6)=3.2
      W(5,7)=3.9
      W(5,8)=4.5
      W(5,9)=5.1
      W(5,10)=5.9
      W(5,11)=6.4
      W(6,1)=.8
      W(6,2)=1.2
      W(6,3)=1.55
      W(6,4)=2.4
      W(6,5)=3.2
      W(6,6)=3.9
      W(6,7)=4.8
      W(6,8)=5.5
      W(6,9)=6.2
      W(6,10)=7.0
      W(6,11)=7.8
      W(7,1)=.94
      W(7,2)=1.4
      W(7,3)=1.8
      W(7,4)=2.8
      W(7,5)=3.7
      W(7,6)=4.7
      W(7,7)=5.6
      W(7,8)=6.5
      W(7,9)=7.5
      W(7,10)=8.4
      W(7,11)=9.1
      W(8,1)=1.2
      W(8,2)=1.65
      W(8,3)=2.2
      W(8,4)=3.4
      W(8,5)=4.5
      W(8,6)=5.5
      W(8,7)=6.6
      W(8,8)=7.8
      W(8,9)=9.0
      W(8,10)=10.0
      W(8,11)=11.0
      W(9,1)=1.3
      W(9,2)=1.9
      W(9,3)=2.6
      W(9,4)=3.9
      W(9,5)=5.2
      W(9,6)=6.5
      W(9,7)=7.9
      W(9,8)=9.1
      W(9,9)=10.5
      W(9,10)=12.0
      W(9,11)=13.0
      W(10,1)=1.6
      W(10,2)=2.4
      W(10,3)=3.1
      W(10,4)=4.8
      W(10,5)=6.2
      W(10,6)=7.9
      W(10,7)=9.2
      W(10,8)=11.0
      W(10,9)=12.5
      W(10,10)=14.0
      W(10,11)=15.5
      W(11,1)=1.8
      W(11,2)=2.7
      W(11,3)=3.6
      W(11,4)=5.5
      W(11,5)=7.3
      W(11,6)=9.0
      W(11,7)=11.2
      W(11,8)=12.7
      W(11,9)=14.5
      W(11,10)=16.0
      W(11,11)=18.0
      W(12,1)=2.3
      W(12,2)=3.3
      W(12,3)=4.3
      W(12,4)=6.5
      W(12,5)=8.7
      W(12,6)=11.2
      W(12,7)=13.0
      W(12,8)=15.5
      W(12,9)=17.5
      W(12,10)=19.0
      W(12,11)=21.0
      W(13,1)=2.55
      W(13,2)=3.8
      W(13,3)=5.0
      W(13,4)=7.5
      W(13,5)=10.0
      W(13,6)=12.5
      W(13,7)=15.0
      W(13,8)=17.5
      W(13,9)=20.0
      W(13,10)=22.5
      W(13,11)=25.0
      W(14,1)=3.0
      W(14,2)=4.5
      W(14,3)=5.9
      W(14,4)=8.9
      W(14,5)=12.0
      W(14,6)=14.5
      W(14,7)=17.5
      W(14,8)=20.5
      W(14,9)=23.5
      W(14,10)=26.5
      W(14,11)=29.5
      W(15,1)=3.4
      W(15,2)=5.0
      W(15,3)=6.7
      W(15,4)=10.0
      W(15,5)=13.5
      W(15,6)=17.0
      W(15,7)=20.0
      W(15,8)=23.0
      W(15,9)=27.0
      W(15,10)=30.0
      W(15,11)=33.0
      W(16,1)=4.0
      W(16,2)=5.9
      W(16,3)=7.9
      W(16,4)=12.0
      W(16,5)=16.6
      W(16,6)=19.5
      W(16,7)=24.0
      W(16,8)=28.0
      W(16,9)=32.0
      W(16,10)=35.0
      W(16,11)=38.0
      W(17,1)=4.5
      W(17,2)=6.8
      W(17,3)=9.0
      W(17,4)=13.5
      W(17,5)=18.0
      W(17,6)=23.0
      W(17,7)=27.5
```

```
      W(17,8)=32.0
      W(17,9)=36.0
      W(17,10)=41.0
      W(17,11)=45.0
      CALL DINT (R,W,TT,17,11,T,RH,WW)
      DO 50 K=1,5
      F1(K)=FC(K)/1000.
      AH(K)=(.1*F1(K)*(T+45.))/((F1(K)/WW**2)+((WW**2)/F1(K)))
   50 CONTINUE
      RETURN
      END
      SUBROUTINE ALPHO(XX,A,BETA,FL,D,DELTAT,T,TO,ZO,ZT,FIG5,AO,YX,Z,PHI
     6,B,C,W30,XT,YT,XO,YO)
      DIMENSION Z(6),C(6),FIG5(6,6),EL(6),YX(17),A(5,17,6)
      DIMENSION SIG(5,10,8),AHB(5),AO(5),DELADO(5),AH(5),DO(10),AA(5)
      COMMON/DIMCOM/TABDIM (120)
   50 FORMAT(57H OBSERVER IS IN THE SHADOW REGION AT THE GIVEN TIME BELO
     6W)
      R=SQRT((XT-XO)**2+(YT-YO)**2)
    5 CONTINUE
      JJ=1
      IF(BETA.LT.2.)GOTO 30
      IF(BETA.EQ.2.)GOTO 10
      IF(BETA.GT.2..AND.BETA.LT.10.)GOTO 15
      GOTO 20
   10 DO 11 I=1,5
      NN=I
      CALL AVEAO(XX,A,BETA,FL,D,NN,AOBAR,YX)
      CALL TABLE1(I,D,BETA,BBT,BBW)
      IF(BBT.EQ.1.0.OR.AOBAR.EQ.0.)GOTO 20
      AO(I)=AOBAR-.3*BBT*(DELTAT+4.5)+.12*BBW*(W30-9.5)
   11 CONTINUE
   15 NN=1
      CALL AVEAO(XX,A,BETA,FL,D,NN,AOBAR,YX)
      CALL TABLE1(1,D,BETA,BBT,BBW)
      IF(BBT.EQ.1.0.OR.AOBAR.EQ.0.)GOTO 20
      AO(1)=AOBAR-.3*BBT*(DELTAT+4.5)+.12*BBW*(W30-9.5)
      JJ=2
   20 DO 22 J=JJ,5
      NN=J
      CALL AVEAO(XX,A,BETA,FL,D,NN,AOBAR,YX)
      IF(AOBAR.EQ.0.)GOTO 30
      AO(J)=AOBAR
   22 CONTINUE
      RETURN
      ENTRY AL
      JJ=1
      R=SQRT((XT-XO)**2+(YT-YO)**2)
      CALL FIG(B,C,ZT,Z,RO,FIG5)
      IF(RO.EQ.0.)GOTO 5
      IF(R.LE.RO)GOTO 5
      IF(R.GE.3.*RO)GOTO 25
      GOTO 27
   25 IF(PHI.LT.110..OR.PHI.GT.150.)GOTO 27
      WRITE (6,50)
      DO 26 I=1,5
      AO(I)=30.
   26 CONTINUE
   29 CONTINUE
      RETURN
   27 DO 28 II=1,5
      NN=II
      CALL AVEAO(XX,A,BETA,FL,RO,NN,AOBAR,YX)
```

```
      IF(AOBAR.EQ.0.)GOTO 30
      AO(II)=AOBAR
      DELADO(II)=(R-RO)*(30.-AO(II))/(2.*RO)
   28 AO(II)=AO(II)+DELADO(II)
      WRITE (6.50)
      RETURN
   30 AO(1)=-1.
      IF(D.LT.6000.)GOTO 35
      RETURN
   35 DO 40 I=1.5
   40 AO(I)=0.
      RETURN
      END
      SUBROUTINE ALOCAT(I,KK,SIG,ZA,ZAA,REWARD)
      DIMENSION SIG(5,10,8),ZAA(8)
      IF(ZA.GT.180.)ZA=360.-ZA
      DO 5 N=1,4
      IF(ZA.GE.ZAA(N).AND.ZA.LT.ZAA(N+1))KKK=N
    5 CONTINUE
      IF(ZA.EQ.180.)KKK=4
      REWARD=((ZA-ZAA(KKK))/(ZAA(KKK+1)-ZAA(KKK)))*(SIG(I,KK,KKK+1)-SIG(
     aI,KK,KKK))+SIG(I,KK,KKK)
      RETURN
      END
      SUBROUTINE AVEAO(XX,A,BETA,EL,D,NN,AOBAR,YX)
      DIMENSION EL(6),YX(17),A(5,17,6)
      IF(D.LT.6000.)GOTO 20
      IF(BETA.LT.EL(1))GOTO 20
      DO 10 N=1,5
      I=N
      IF(BETA.GE.EL(N).AND.BETA.LT.EL(N+1))GOTO 30
    1 CONTINUE
      IF(BETA.EQ.EL(6))GOTO 30
   20 CONTINUE
      AOBAR=0.
      RETURN
   30 DK=D/1000.
      DO 40 K=1,15
      J=K
      IF(DK.GE.YX(K).AND.DK.LT.YX(K+1))GOTO 50
   40 CONTINUE
      IF(DK.EQ.YX(16))GOTO 50
      GOTO 20
   50 CALL INTERP(DK,I,J,A,NN,BETA,EL,VALUE,YX)
      AOBAR=VALUE
      RETURN
      END
      SUBROUTINE DEFREE(SNL,SAMB,PROB,ARC)
      DIMENSION SL(19),QI1(19),QI2(19)
      DIMENSION P(12),BAND(13),BANMID(12),PD(12)
      DATA SL/10.,15.,20.,25.,30.,35.,40.,45.,50.,55.,60.,65.,70.,75.,80
     1.,85.,90.,95.,100./
      DATA QI1/.76,.47,.34,.29,.27,.27,.27,.27,.27,.27,.27,.27,.27,.26,.2
     25,.24,.22,.20,.19/
      DATA QI2/.84,.52,.40,.34,.32,.32,.32,.32,.32,.32,.32,.32,.32,.32,.
     332,.32,.31,.29,.27/
      DATA P/.005,.017,.044,.092,.150,.192,.192,.150,.092,.044,.017,.005
     6/
      PROB=0.
      IF(SAMB.LE.0..OR.SNL.LE.0.)GOTO 25
      TAMB=(ALOG10(SAMB)+1.2)/0.03
      SSS=(ALOG10(SNL)+1.2)/0.03
      IF(TAMB.LT.15..OR.SSS.LT.15.)GOTO 25
```

```
      K=0
      DO 1 I=1,18
      IF(TAMB.GE.SL(I).AND.TAMB.LT.SL(I+1))K=I
    1 CONTINUE
      IF(K.EQ.0)GOTO 5
      XBAR1=(QI1(K)+QI2(K))/2.
      XBAR2=(QI1(K+1)+QI2(K+1))/2.
      XBAR=((TAMB-SL(K))/(SL(K+1)-SL(K)))*(XBAR2-XBAR1)+XBAR1
      A=((TAMB-SL(K))/(SL(K+1)-SL(K)))*(QI1(K+1)-QI1(K))+QI1(K)
      B=((TAMB-SL(K))/(SL(K+1)-SL(K)))*(QI2(K+1)-QI2(K))+QI2(K)
      SIGMA=SQRT((A-XBAR)**2+(B-XBAR)**2)
      BAND(1)=XBAR-3.*SIGMA
      DO 2 I=2,13
    2 BAND(I)=BAND(I-1)+SIGMA/2.
      DO 3 I=1,12
    3 BANMID(I)=(BAND(I)+BAND(I+1))/2.
      DELTA=SSS-TAMB
      DO 4 I=1,12
      PD(I)=(DELTA/BANMID(I))-1.
      IF(PD(I).LT.0.)PD(I)=0.0
      IF(PD(I).GT.1.0)PD(I)=1.0
    4 PROB=PD(I)*P(I)+PROB
      IF(PROB.LE.0.)PROB=0.
      RETURN
   25 PROB=0.
      RETURN
    5 ARC=0.
      RETURN
      END
      SUBROUTINE DINT (R,W,TT,I,J,T,RH,WW)
      DIMENSION R(I,J), W(I,J), TT(I), X(100), Y(100)
C
C     R(I,J) CONTAINS INDEPENDENT VARIABLES, VALUES MUST
C     HAVE SMALLEST VALUE AT J=1
C     W(I,J) CONTAINS DEPENDENT VARIABLES
C     TT(I) IS THE PARAMETER THAT DETERMINES WHICH OF THE
C     I TH CURVE OF R(I,J) AND W(I,J) TO CONSIDER
C     T IS THE KNOWN PARAMETER VALUE
C     RH IS THE KNOWN INDEPENDENT VARIABLE
C     WW IS THE DEPENDENT VALUE TO BE SOLVED
C
      IF(TT(1)-T)1,3,2
    1 IF(T-TT(I))9,6,5
    2 WRITE (6,17)
    3 DO 4 II=1,J
      X(II)=R(1,II)
    4 Y(II)=W(1,II)
      GOTO 8
    5 WRITE (6,18)
    6 DO 7 II=1,J
      X(II)=R(I,II)
    7 Y(II)=W(I,II)
    8 CALL DVDINT (RH,WW,X,Y,J,2)
      RETURN
    9 L=2
   10 IF(TT(L)-T)11,12,14
   11 L=L+1
      GOTO 10
   12 DO 13 II=1,J
      X(II)=R(L,II)
   13 Y(II)=W(L,II)
      GOTO 8
   14 LL=L-1
```

```
      DO 15 II=1,J
      X(II)=R(LL,II)
   15 Y(II)=W(LL,II)
      CALL DVDINT (RH,Z,X,Y,J,2)
      DO 16 II=1,J
      X(II)=R(L,II)
   16 Y(II)=W(L,II)
      CALL DVDINT (RH,ZZ,X,Y,J,2)
      WW=Z+(ZZ-Z)*(T-TT(LL))/(TT(L)-TT(LL))
      RETURN
   17 FORMAT(20H VALUE OF T TO SMALL)
   18 FORMAT(20H VALUE OF T TO LARGE)
      END
      SUBROUTINE DVDINT (X,FX,XT,FT,NP,ND)
      DIMENSION XT(NP), FT(NP), TT(16)
      N=ND
      N1=(N-1)/2
      N2=N/2
      N3=NP-N2+1
      IF(NP-N)18,1,1
    1 N4=N1+2
      IF(XT(1)-XT(2))2,26,19
    2 CONTINUE
      IF(X-2.*XT(1)+XT(2))15,15,3
    3 IF(X-2.*XT(NP)+XT(NP-1))4,4,15
    4 IF(NP.LT.10)GOTO 6
      N5=NP-N
    5 N5=N5/2
      N6=N4+N5
      IF(XT(N6).LT.X)N4=N6
      IF(N5.GT.1)GOTO 5
    6 IF(X-XT(N4))9,7,7
    7 IF(N4-N3)8,9,8
    8 N4=N4+1
      GOTO 6
    9 N4=N4-1
      N5=N4-N1
      DO 10 I=1,N
      TT(I)=FT(N5)
   10 N5=N5+1
      L=(N+1)/2
      TP=TT(L)
      N6=N4
      N7=N4+1
      JU=1
      N2=N-1
      UN=1.0
      DO 14 J=1,N2
      N5=N4-N1
      N3=N-J
      DO 11 I=1,N3
      N8=N5+J
      TT(I)=(TT(I+1)-TT(I))/(XT(N8)-XT(N5))
   11 N5=N5+1
      GOTO (12,13), JU
   12 UN=UN*(X-XT(N6))
      JU=2
      N6=N6-1
      GOTO 14
   13 UN=UN*(X-XT(N7))
      JU=1
      N7=N7+1
      L=L-1
```

```
   14 TR=TR+UN*TT(L)
      FX=TR
      RETURN
   15 IF(X-XT(1))16,16,17
   16 TR=FT(1)
      FX=TR
      RETURN
   17 TR=FT(NP)
      FX=TR
      RETURN
   18 WRITE (6,27) NP,ND
      GOTO 15
   19 IF(X-2.*XT(1)+XT(2))20,15,15
   20 IF(X-2.*XT(NP)+XT(NP-1))15,21,21
   21 IF(NP.LT.10)GOTO 23
      N5=NP-N
   22 N5=N5/2
      N6=N4+N5
      IF(XT(N6).GT.X)N4=N6
      IF(N5.GT.1)GOTO 22
   23 IF(X-XT(N4))24,24,9
   24 IF(N4-N3)25,9,25
   25 N4=N4+1
      GOTO 23
   26 WRITE (6,28) XT(1)
      GOTO 15
C
   27 FORMAT(21H TABLE TOO SMALL NP= ,I5,6H  ND= ,I5,2X,6HDVDINT)
   28 FORMAT(23H CONSTANT TABLE XT(1)= ,E14.7,2X,6HDVDINT)
      END
      SUBROUTINE FLIGHT(AX,AY,AZ,VX,VY,VZ,XT,YT,ZT,DT)
      VX=VX+AX*DT
      VY=VY+AY*DT
      VZ=VZ+AZ*DT
      XT=XT+VX*DT
      YT=YT+VY*DT
      ZT=ZT+VZ*DT
      RETURN
      END
      SUBROUTINE FIG(B,C,ZT,Z,VALUE,FIG5)
      DIMENSION Z(6),FIG5(6,6),C(6)
      B=ABS(B)
      I=0
      DO 15 N=1,5
      IF(B.GE.C(N).AND.B.LT.C(N+1))I=N
   15 CONTINUE
      IF(I.EQ.0)GOTO 20
      GOTO 30
   20 CONTINUE
      GOTO 37
   30 J=0
      DO 35 K=1,5
      IF(ZT.GE.Z(K).AND.ZT.LT.Z(K+1))J=K
   35 CONTINUE
      IF(J.EQ.0)GOTO 20
      CALL INTEP(FIG5,ZO,Z,B,C,J,I,VALUE),RETURNS(36,37)
   36 RETURN
   37 VALUE=0.
      RETURN
      END
```

```
      SUBROUTINE INTEP(FIG5,Z0,Z,B,C,J,I,VALUE),RETURNS(M,N)
      DIMENSION FIG5(6,6),C(6),Z(6)
      IF(FIG5(J+1,I+1).EQ.0.)GOTO 20
      IF(FIG5(J+1,I).EQ.0.)GOTO 20
      SH1=FIG5(J,I+1)
      SH2=FIG5(J,I)
      SH3=FIG5(J+1,I+1)
      SH4=FIG5(J+1,I)
      B1=C(I)
      B2=C(I+1)
      Z1=Z(J)
      Z2=Z(J+1)
      B=ABS(B)
      SHA=SH1+((SH2-SH1)/(B2-B1))*(B-B1)
      SHB=SH3+((SH4-SH3)/(B2-B1))*(B-B1)
      VALUE=(Z0/(Z1+Z2))*(SHB-SHA)+SH1
      VALUE=VALUE*1000.
      RETURN N
   20 CONTINUE
      VALUE=0.
      RETURN M
      END
      SUBROUTINE INTERP(XX,I,J,A,N,BETA,EL,VALUE,YX)
      DIMENSION A(5,17,6),YX(17),EL(6)
      IF(A(N,J+1,I+1).EQ.0.)GOTO 20
      AVE=A(N,J,I)+((A(N,J+1,I)-A(N,J,I))/(YX(J+1)-YX(J)))*(XX-YX(J))
      EVA=A(N,J,I+1)+((A(N,J+1,I+1)-A(N,J,I+1))/(YX(J+1)-YX(J)))*(XX-YX(
     1J))
      VALUE=((BETA-EL(I))/(EL(I+1)-EL(I)))*(AVE-EVA)+EVA
      RETURN
   20 CONTINUE
      VALUE=0.
      RETURN
      END
      SUBROUTINE ORDER (X)
      DIMENSION X(5)
      KK=1
      DO 10 J=1,4
      L=5-J
      DO 10 K=1,L
      IF(X(K)-X(K+1))10,10,6
    6 IF(X(KK).LE.X(K))KK=K
   10 CONTINUE
      DO 20 JJ=1,5
      IF(JJ.EQ.KK)GOTO 20
      X(JJ)=X(JJ)*0.3
   20 CONTINUE
      RETURN
      END
      SUBROUTINE RELPOS(X,Y,Z,XT,YT,ZT,AX,BETA,D,VX,VY,VZ)
      PIE=3.141593
      XX=XT-X
      YY=YT-Y
      ZZ=ZT-Z
      D=SQRT(XX**2+YY**2+ZZ**2)
      VV=SQRT(VX**2+VY**2+VZ**2)
      TT=SQRT(XT**2+YT**2+ZT**2)
      IF(VV.EQ.0..OR.TT.EQ.0.)GOTO 30
      AX=ACOS((VX*XT+VY*YT+VZ*ZT)/(VV*TT))
   50 CONTINUE
      BETA=ASIN(ZZ/D)
      GOTO 15
   30 AX=0.
```

```
   21 IF(D.NE.0.)GOTO 50
      BETA=PIE/2.
   15 CONTINUE
      BETA=BETA*57.2957
      AX=AX*57.2957
      IF(XT.EQ.0..AND.YT.EQ.0.)WRITE (6,16)
   16 FORMAT(16H TARGET OVERHEAD)
      RETURN
      END
      SUBROUTINE SHADOW(XX,A,BETA,EL,D,DELTAT,T,TO,FIG5,AO,PHI,W30,XT,YT
     1,ZT,XO,YO,ZO,YX,C)
      DIMENSION Z(6),C(6),FIG5(6,6),EL(6),YX(17),A(5,17,6)
      DIMENSION SIG(5,10,8),AMB(5),AO(5),DELADO(5),AH(5),DO(10),AA(5)
      COMMON/DIMCOM/TABDIM (120)
      SK=(T-TO)/ALOG10(ZT/ZO)
      BT=4.*SK*(1./10.**4)
      BW=1.5*W30*COS(PHI/57.2957)*(1./10.**4)
      B=BT+BW
      CW=W30*COS(PHI/57.2957)
      IF(CW.GT.0.)GOTO 20
      IF(CW.EQ.0..AND.BT.LT.0.)GOTO 10
      IF(CW.LT.0.)GOTO 10
      GOTO 20
C     NO SHADOW REGION
   10 CALL ALPHO(XX,A,BETA,EL,D,DELTAT,T,TO,ZO,ZT,FIG5,AO,YX,Z,PHI,B,C,W
     630,XT,YT,XO,YO)
      RETURN
   20 IF(BW.EQ.(-BT))GOTO 21
      GOTO 22
   21 XXX=(-BT)/(1.5*W30*(1./10.**4))
      IF(XXX.GT.1.0.OR.XXX.LT.-1.0)GOTO 10
      PHIC=ACOS(XXX)
      PHIC=PHIC*57.2957
      IF(PHIC.LT.90..AND.PHIC.GT.270.)GOTO 10
      IF((PHI-PHIC).LT.60.)GOTO 10
   22 CONTINUE
      IF(ABS(B).GT.C(6).OR.ABS(B).LT.C(1))GOTO 10
      CALL AL(XX,A,BETA,EL,D,DELTAT,T,TO,ZO,ZT,FIG5,AO,YX,Z,PHI,B,C,W30,
     6XT,YT,XO,YO)
      RETURN
      END
      FUNCTION TAB(I,J,K,L)
      COMMON/DICOM/TABDIM (120)
C     FUNCTIONAL FOR COMPUTING MULTIPLY OR N INDICES
      INDEX=I+5*(J-1+4*(K-1+3*(L-1)))
      TAB=TABDIM(INDEX)
C     I-INNER MOST INDEX---5 IS ITS NUMBER
C     J-NEXT INDEX---4 IS ITS NUMBER
C     K-NEXT INDEX---3 IS ITS NUMBER
C     L-OUTERMOST INDEX---IS COMPUTED
      RETURN
      END
      SUBROUTINE TABLE1(N,D,BETA,BBT,BBW)
      COMMON/DIMCOM/TABDIM (120)
      IF(BETA.LT.2.)J=0
      IF(BETA.GE.2..AND.BETA.LT.3.)J=1
      IF(BETA.GE.3..AND.BETA.LT.5.)J=2
      IF(BETA.GE.5..AND.BETA.LT.7.5)J=2
      IF(BETA.GE.7.5.AND.BETA.LT.10.5)J=3
      IF(J.EQ.0)GOTO 50
      GOTO 55
   50 CONTINUE
      BBT=1.0
```

```
      RETURN
   55 I=0
      IF(D.GE.1000..AND.D.LT.1500.)I=1
      IF(D.GE.1500..AND.D.LT.2000.)I=2
      IF(D.GE.2000..AND.D.LT.2500.)I=2
      IF(D.GE.2500..AND.D.LT.3000.)I=3
      IF(D.GE.3000..AND.D.LT.3500.)I=3
      IF(D.GE.3500..AND.D.LE.4000.)I=4
      IF(I.EQ.0)GOTO 50
      BBT=TAB(N,I,J,1)
      BBW=TAB(N,I,J,2)
      IF(TAB(N,I,J,1).EQ.1.0)GOTO 50
      RETURN
      END
      SUBROUTINE VEG(BETA,D,AT,N,AC,E,EE)
      DIMENSION AT(5),AC(5,4),E(4),EE(4)
      IF(BETA.GT.E(4))GOTO 15
      NN=0
      DO 10 I=1,3
      IF(BETA.GE.E(I).AND.BETA.LT.E(I+1))NN=I
   10 CONTINUE
      IF(NN.EQ.0)GOTO 15
      C=((BETA-E(NN))/(E(NN+1)-E(NN)))*(EE(NN+1)-EE(NN))+EE(NN)
      GOTO 20
   15 C=0.
   20 DO 30 I=1,5
   30 AT(I)=AC(I,N)*C*(D/1000.)
      RETURN
      END
      SUBROUTINE WEED(WANO,WIND,FEET,XT,YT,ZT,X,Y,Z,PHI,W30)
      DATA A/57.2957/
      W30=WIND/(1.+.27*ALOG10(FEET/30.))
      WX=SIN(WANO/A)
      WY=COS(WANO/A)
      DOT=WX*(X-XT)+WY*(Y-YT)
      B=SQRT((XT-X)**2+(YT-Y)**2+(ZT-Z)**2)
      PHI=ACOS(DOT/B)*A
      RETURN
      END
```

59.0	80.0	87.0	85.0	82.0	77.0	77.0	75.0
97.0	92.0	90.0	88.0	85.0	75.0	66.0	63.0
50.0	55.0	50.0	47.0	45.0	45.0	45.0	35.0
110.0	108.0	110.0	112.0	105.0	100.0	90.0	80.0
59.0	67.0	68.0	70.0	62.0	62.0	63.0	57.0
100.	100.	100.	100.	100.	100.	100.	100.
100.	100.	100.	100.	100.	100.	100.	100.
100.	100.	100.	100.	100.	100.	100.	100.
100.	100.	100.	100.	100.	100.	100.	100.
100.	100.	100.	100.	100.	100.	100.	100.

```
63.3      61.0      64.0      58.0      30.0
35.       37.       40.       41.       38.
0.        45.       90.       135.      180.      225.      270.      360.
.0001      .0002     .0005     .001      .002     .005
2.        5.        10.       15.       30.       90.
.6        .7        .8        .9        1.0       2.0       3.0       4.0
5.0       6.0       7.0       8.0       9.0       10.0      20.0      30.0
40.0
1.        8.7
.8        6.45
.6        4.        7.        10.
.4        2.8       5.0       7.0       7.0       9.0
.15       2.0       3.6       5.0       6.4       7.8
0.        1.3       2.3       3.2       4.1       5.0
0.        200.      400.      600.      800.      1000.
 SDON
 TABDIH(1)=-2.5,  -1.2, 0.0,  -0.5,  -1.2,
 -1.5,     -1.2,     0.9,      -0.6,     -1.4,
 1.0,      -1.2,     1.7,      -1.1,     1.0,
 1.0,      1.0,      1.0,      -2.0,     1.0,
 -0.7,     1.0,      1.0,      1.0,      1.0,
 -1.0,     1.0,      1.0,      1.0,      1.0,
 1.0,      1.0,      1.0,      1.0,      1.0,
 1.0,      1.0,      1.0,      1.0,      1.0,
 1.2,      1.0,      1.0,      1.0,      1.0,
 0.2,      1.0,      1.0,      1.0,      1.0,
 1.0,      1.0,      1.0,      1.0,      1.0,
 1.0,      1.0,      1.0,      1.0,      1.0,
 4.8,      1.2,      0.0,      2.6,      0.4,
 4.4,      1.3,      0.0,      3.9,      0.0,
 1.0,      0.0,      0.0,      4.4,      1.0,
 1.0,      1.0,      1.0,      4.0,      1.0,
 2.4,      1.0,      1.0,      1.0,      1.0,
 1.5,     1.0,      1.0,      1.0,      1.0,
 1.0,      1.0,      1.0,      1.0,      1.0,
 1.0,      1.0,      1.0,      1.0,      1.0,
 -1.7,     1.0,      1.0,      1.0,      1.0,
 -1.6,     1.0,      1.0,      1.0,      1.0,
 1.0,      1.0,      1.0,      1.0,      1.0,
 1.0,      1.0,      1.0,      1.0,      1.0,
 S
2.3       5.5       6.5       6.5       6.5
4.0       9.6       10.8      10.8      10.8
6.0       9.0       12.0      15.0      18.0
10.0      13.0      16.0      24.0      35.0
0.        2.        4.        6.
1.0       .20       .12       .03
0.        0.        .28       .28       .30
0.        .22       .54       .55       .62
.15       .60       1.1       1.1       1.3
.65       1.5       2.2       2.2       2.48
1.9       3.6       4.4       4.4       4.8
5.0       7.7       8.8       8.8       9.8
12.0      15.2      17.5      17.5      20.0
24.0      32.0      34.6      34.6      40.0
48.0      63.0      69.6      69.6      78.0
97.0      125.0     135.0     135.0     158.0
195.0     250.0     260.0     260.0     310.0
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REFERENCES

1. Balahan, Ronald A., An Aural Detection Model for Low Flying Aircraft, AMSAA Technical Report No. 60, May 1972.

2. Sabine, H. J., Sound Propagation Near the Earth's Surface as Influenced by Weather Conditions, WADC Technical Report No. 57-353, Part IV, January 1961.

3. Sabine, H. J., Karplus, H. B., and Burkhard, M. D., Sound Propagation Near the Earth's Surface as Influenced by Weather Conditions, WADC Technical Report No. 57-353, Part II, December 1960.

4. Harris, C. M., Handbook of Noise Control, "The Loudness of Sounds," Chapter 5, McGraw-Hill Book Company, 1957.

5. Miller, George A., "Sensitivity to Changes in the Intensity of White Noise and Its Relation to Masking and Loudness," Journal of the Acoustical Society of America, Vol. 19, No. 4, March 1947.

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